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JOURNAL

AND

PROCEEDINGS

OF THE

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OF

NEW SOUTH WALES

FOR

1901.

(INCORPORATED 1881.

VOL. XXXV.

EDITED BY

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THE AUTHORS OF PAPERS ARE ALONE RESPONSIBLE FOR THE STATEMENTS MADE AND THE OPINIONS EXPRESSED THEREIN.

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1901.

NOTICE.

The Royal Society of New South Wales originated in 1821 as the "Philosophical Society of Australasia"; after an interval of inactivity, it was resuscitated in 1850, under the name of the "Australian Philosophical Society," by which title it was known until 1856, when the name was changed to the "Philosophical Society of New South Wales"; in 1866, by the sanction of Her Most Gracious Majesty the Queen, it assumed its present title, and was incorporated by Act of the Parliament of New South Wales in 1881.

TO AUTHORS.

Authors of papers desiring illustrations are advised to consult the editors (Honorary Secretaries) before preparing their drawings. Unless otherwise specially permitted, such drawings should be carefully executed to a large scale on smooth white Bristol board in intensely black Indian ink; so as to admit of the blocks being prepared directly therefrom, in a form suitable for photographic "process." The size of a full page plate in the Journal is $4\frac{1}{4}$ in. × $6\frac{3}{4}$ in. The cost of all original drawings, and of colouring plates must be borne by Authors.

ERRATA.

Page 51, last line, for "Macksell," read "*Mackrell.*"
„ 84, fourth line from bottom, transpose northern and southern.
„ 88, third line, for "similar," read "*similarly.*"
„ 92, fifth line, for "such," read "*each.*"
„ 129, line twenty-seven, for "gutteral," read "*guttural.*"
„ 139, twenty-fifth line, for "thou," read "*them.*"
„ 145, eighth line from bottom, for "them," read "*him.*"
„ 153, lines seven to eleven, the words beginning with "Un-" should begin with "*Ngun-*"

PUBLICATIONS.

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President:

H. C. RUSSELL, B.A. C.M.G., F.R.S.

Vice-Presidents:

Prof. T. W. E. DAVID, B.A., F.R.S.	W. M. HAMLET, F.I.C., F.C.S.
HENRY DEANE, M.A., M. Inst. C.E.	Prof. LIVERSIDGE, M.A., LL.D., &c.

Hon. Treasurer:

H. G. A. WRIGHT, M.R.C.S. *Eng.*, (deceased 14th Sept., 1901) succeeded by D. CARMENT, F.I.A., F.F.A.

Hon. Secretaries:

J. H. MAIDEN, F.L.S.	G. H. KNIBBS, F.R.A.S.

Members of Council:

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H. A. LENEHAN, F.R.A.S.	HENRY G. SMITH, F.C.S.
CHARLES MOORE, F.R.B.S.	ANDERSON STUART, M.D., LL.D.
E. F. PITTMAN, A.R.S.M.	J. STUART THOM
F. H. QUAIFE, M.A., M.D.	Prof. WARREN, M. Inst. C.E., Wh.Sc.

Assistant Secretary:

W. H. WEBB.

FORM OF BEQUEST.

I bequeath the sum of £ to the ROYAL SOCIETY OF NEW SOUTH WALES, Incorporated by Act of the Parliament of New South Wales in 1881, and I declare that the receipt of the Treasurer for the time being of the said Corporation shall be an effectual discharge for the said Bequest, which I direct to be paid within calendar months after my decease, without any reduction whatsoever, whether on account of Legacy Duty thereon or otherwise, out of such part of my estate as may be lawfully applied for that purpose.

[Those persons, who feel disposed to benefit the Royal Society of New South Wales by Legacies, are recommended to instruct their Solicitors to adopt the above Form of Bequest.]

ROYAL SOCIETY OF NEW SOUTH WALES.

ACT OF INCORPORATION.

An Act to incorporate a Society called "The Royal Society of New South Wales." [16 December, 1881.]

Preamble

WHEREAS a Society called (with the sanction of Her Most Gracious Majesty the Queen) "The Royal Society of New South Wales" has under certain rules and by-laws been formed at Sydney in the Colony of New South Wales for the encouragement of studies and investigations in Science Art Literature and Philosophy And whereas the Council of the said Society is at the present time composed of the following office-bearers and members His Excellency the Right Honorable Lord Augustus Loftus P.C. G.C.B. Honorary President The Honorable John Smith C.M.G. M.D. LLD. President and Charles Moore Esquire F.L.S. Director of the Botanic Gardens Sydney and Henry Chamberlaine Russell Esquire B.A. (Sydney) F.R.A.S. F.M.S. (London) Government Astronomer for New South Wales Vice-Presidents and H. G. A. Wright Esquire M.R.C.S. Honorary Treasurer Archibald Liversidge Esquire Associate of the Royal School of Mines London Fellow of the Institute of Chemistry of Great Britain and Ireland and Professor of Geology and Mineralogy in the University of Sydney and Carl Adolph Leibius Esquire Doctor of Philosophy of the University of Heidelberg Fellow of the Institute of Chemistry of Great Britain and Ireland Honorary Secretaries W. A. Dixon Esquire Fellow of the Institute of Chemistry of Great Britain and Ireland G. D. Hirst Esquire Robert Hunt Esquire Associate of the Royal School of Mines London Deputy Master Sydney Branch Royal Mint Eliezer L.

Montefiore Esquire Christopher Rolleston Esquire C.M.G. Charles Smith Wilkinson Esquire Government Geologist Members of the Council. And whereas it is expedient that the said Society should be incorporated and should be invested with the powers and authorities hereinafter contained Be it therefore enacted by the Queen's Most Excellent Majesty by and with the advice and consent of the Legislative Council and Legislative Assembly of New South Wales in Parliament assembled and by the authority of the same as follows:—

Interpretation clause

1. For the purposes of this Act the following words in inverted commas shall unless the contex otherwise indicate bear the meaning set against them respectively—

"Corporation" the Society hereby incorporated.

"Council" the Members of the Council at any duly convened meeting thereof at which a quorum according to the by-laws at the time being shall be present.

"Secretary" such person or either one of such persons who shall for the time being be the Secretary or Secretaries honorary or otherwise of the said Society (saving and excepting any Assistant Secretary of the said Society.)

Incorporation clause

2. The Honorary President the President Vice-Presidents Officers and Members of the said Society for the time being and all persons who shall in manner provided by the rules and by-laws for the time being of the said Society become members thereof shall be for the purposes hereinafter mentioned a body corporate by the name or style of "The Royal Society of New South Wales" and by that name shall and may have perpetual succession and a common seal and shall and may enter into contracts and sue and be sued plead and be impleaded answer and be answered unto defend and be defended in all Courts and places whatsoever and may prefer lay and prosecute any indictment information and prosecution against any person whomsoever and any summons or other writ and any notice or other proceeding which it may be requisite to serve upon the Corporation may be served upon the Secretary or one of the Secretaries as the case may be or if there be no Secretary or if the Secretaries or Secretary be absent from the Colony then upon the President or either of the Vice-Presidents.

3. The present rules and by-laws of the said Society shall be deemed and considered to be and shall be the rules and by-laws of the said Corporation save and except in so far as any of them are or shall or may be altered varied or repealed under the powers for that purpose therein contained or are or may be inconsistent or incompatible with or repugnant to any of the provisions of this Act or any of the laws now or hereinafter to be in force in the said Colony. **Rules and By-laws**

4. The Corporation shall have power to purchase acquire and hold lands and any interest therein and also to sell and dispose of the said lands or any interest therein and all lands tenements hereditaments and other property of whatever nature now belonging to the said Society under the said rules and by-laws or vested in Trustees for them shall on the passing of this Act be vested in and become the property of the said Corporation subject to all charges claims and demands in anywise affecting the same. **Power to acquire and hold and to sell lands &c.**

5. The ordinary business of the Corporation in reference to its property shall be managed by the Council and it shall not be lawful for individual members to interfere in any way in the management of the affairs of the Corporation except as by the rules and by-laws for the time being shall be specially provided. **Ordinary business to be managed by the Council**

6. The Council shall have the general management and superintendence of the affairs of the Corporation and excepting the appointment of President and Vice-Presidents and other honorary officers who shall be appointed as the by-laws of the Society shall from time to time provide the Council shall have the appointment of all officers and servants required for carrying out the purposes of the Society and of preserving its property and it may also define the duties and fix the salaries of all officers. Provided that if a vacancy shall occur in the Council during any current year of the Society's proceedings it shall be lawful for the Council to elect a member of the Society to fill such vacancy for the unexpired portion of the then current year. The Council may also purchase or rent land houses or offices and erect buildings or other structures for any of the purposes for which the Society is hereby incorporated and may borrow money for the purposes of the Corporation on mortgages of the real and chattel property of the Corporation or any part thereof or may borrow money without security provided that the amount so borrowed without security shall never exceed **Powers of Council**

in the aggregate the amount of the income of the Corporation for the last preceding year and the Council may also settle and agree to the covenants powers and authorities to be contained in the securities aforesaid.

Liability of members

7. In the event of the funds and property of the Corporation being insufficient to meet its engagements each member thereof shall in addition to his subscription for the then current year be liable to contribute a sum equal thereto towards the payment of such engagements but shall not be otherwise individually liable for the same and no member who shall have commuted his annual subscription shall be so liable for any amount beyond that one year's subscription.

Custody of common seal

8. The Council shall have the custody of the common seal of the Corporation and have power to use the same in the affairs and business of the Corporation and for the execution of any of the securities aforesaid and may under such seal authorize any person without such seal to execute any deed or deeds and do such other matter as may be required to be done on behalf of the Corporation but it shall not be necessary to use the said seal in respect of the ordinary business of the Corporation nor for the appointment of their Secretaries Solicitor or other officers.

Certified copy of rules and by-laws to be evidence

9. The production of a printed or written copy of the rules and by-laws of the Corporation certified in writing by the Secretary or one of the Secretaries as the case may be to be a true copy and having the common seal of the Corporation affixed thereto shall be conclusive evidence in all Courts of such rules and by-laws and of the same having been made under the authority of this Act.

Elections not made in due time may be made subsequently

10. In case any of the elections directed by the rules and by-laws for the time being of the Corporation to be made shall not be made at the times required it shall nevertheless be competent to the Council or to the members as the case may be to make such elections respectively at any ordinary meeting of the Council or at any annual or special general meeting held subsequently.

Secretary may represent Corporation for certain purposes

11. The Secretary or either one of the Secretaries may represent the Corporation in all legal and equitable proceedings and may for and on behalf of the Corporation make such affidavits and do such acts and sign such documents as are or may be required to be done by the plaintiff or complainant or defendant respectively in any proceedings to which the Corporation may be parties.

INDEX TO RULES.

RULES.

(Revised Oct. 1, 1879.)

Rule III. amended June 5, 1890. Rules IV., XIV., XVII., XIX., XXVI., XXXI., XL., XLIX, amended June 1, 1898. Rules III., V., VI., amended May 2. 1900. Rules II., III., XVII., XVIII., XXV., XXXV., amended May 1, 1901.

Object of the Society.

I. The object of the Society is to receive at its stated meetings original papers on Science, Art, Literature, and Philosophy, and especially on such subjects as tend to develop the resources of Australia, and to illustrate its Natural History and Productions.

Patrons and Vice-Patrons.

II. The Governor-General shall be invited to become Patron, and the State Governor of New South Wales, Vice-Patron of the Society.

Officers.

III. The Officers of the Society shall consist of the President, who shall hold office for not more than one year continuously, but shall be eligible for re-election after the lapse of one year; four Vice-Presidents, an Honorary Treasurer, and two Honorary Secretaries, who, with ten other members, shall constitute the Council for the management of the affairs of the Society.

Election of Officers and Council.

IV. The President, Vice-Presidents, Honorary Secretaries, Honorary Treasurer, and the *ten* other members of Council, shall be elected annually by ballot at the first General Meeting in the month of May; hereinafter called the Annual General Meeting.

V. It shall be the duty of the Council each year to prepare a list containing the names of members whom they recommend for election to the respective offices of President, Vice-Presidents, Hon. Secretaries, and Hon. Treasurer, together with the names of *ten* other members whom they recommend for election as ordinary members of Council.

The names thus recommended shall be proposed at one meeting of the Council, and agreed to at a subsequent meeting.

Such list shall be exhibited in the Society's Rooms at least one calendar month before the day appointed for the Annual General Meeting. Any member of the Society not disqualified by Rules XVI., XVII., or XVIII., may be nominated for the position of President, Vice-President, Honorary Treasurer, Honorary Secretary, or Member of the Council, provided that his candidature shall have been notified to the Honorary Secretary or Secretaries under the hands of two qualified voters—such notification being countersigned by the nominee—at least fourteen days before the day appointed for the Annual General Meeting.

A complete list showing the names of those recommended for election by the Council, and those nominated as in the last preceding clause, shall be sent to each member of the Society, at least seven days before the day appointed for the Annual General Meeting.

The name of each member voting shall be entered into a book, kept for that purpose, by two Scrutineers elected by the members present.

No ballot for the election of members of Council, or of new members, shall be valid unless twenty members at least shall record their votes.

VI. The balloting list for the election of Officers and Members of Council shall contain a list of the names of those recommended by the Council and also of those otherwise nominated as provided for in Rule V. Heading the former, the words "Recommended by Council" shall be inserted, and opposite the latter the names of the nominators.

Vacancies in the Council during the year.

VII. Any vacancies occurring in the Council of Management during the year may be filled up by the Council.

Candidates for admission.

VIII. Candidates must be at least twenty-one years of age.

Every candidate for admission as an ordinary member of the Society shall be recommended according to a prescribed form of certificate by not less than three members, to two of whom the candidate must be personally known.

Such certificate must set forth the name, place of residence, and qualifications of the candidate.

The certificate shall be read at the three Ordinary General Meetings of the Society next ensuing after its receipt, and during the intervals between those three meetings, it shall be exhibited in a conspicuous place in one of the rooms of the Society.

The vote as to admission shall take place by ballot, at the Ordinary General Meeting at which the certificate is appointed to be read the third time, and immediately after such reading.

At the ballot the assent of at least four-fifths of the members voting shall be requisite for the admission of the candidate.

Entrance Fee and Subscriptions.

IX. The entrance money paid by members on their admission shall be Two Guineas; and the annual subscription shall be Two Guineas, payable in advance; but members elected prior to December, 1879, shall be required to pay an annual subscription of One Guinea only as heretofore.

The amount of ten annual payments may be paid at any time as a life composition for the ordinary annual payment.

X. The entrance fee and first annual subscription shall be paid within two months from the date of election; otherwise the election shall be void.

The Council may, however, in special cases, extend the period within which these payments must be made.

XI. Composition fees shall be treated as capital, and shall be devoted to the Building Fund Account, or invested.

New members to be informed of their election.

XII. Every new member shall receive due notification of his election, and be supplied with a copy of the obligation (No. 3 in

Appendix), together with a copy of the Rules of the Society, a list of members, and a card of the dates of meeting.

Members shall sign Rules—Formal admission.

XIII. Every member who has complied with the preceding Rules shall at the first Ordinary General Meeting at which he shall be present sign a duplicate of the aforesaid obligation in a book to be kept for that purpose, after which he shall be presented by some member to the Chairman, who addressing him by name, shall say:—"In the name of the Royal Society of New South Wales I admit you a member thereof."

Annual Subscription when due.

XIV. Annual subscriptions shall become due on the first day of May for the year then commencing. The entrance fee and first year's subscription of a new member shall become due on the day of his election.

XV. Persons elected on or after the first day of October in any year shall pay the annual contribution as in advance for the following year, but in every case within two months after notification of their election has been made to them by the Honorary Secretary.

Members whose subscriptions are unpaid not to enjoy privileges.

XVI. An elected member shall not be entitled to attend the meetings or to enjoy any privilege of the Society, nor shall his name be printed in the list of the Society, until he shall have paid his admission fee and first annual subscription, and have returned to the Secretaries the obligation signed by himself.

Subscriptions in arrears.

XVII. Members who have not paid their subscriptions for the current year, on or before the 31st of May, shall be informed of the fact by the Hon. Treasurer.

No member shall be entitled to vote or hold office while his subscription for the previous year remains unpaid.

The name of any member who shall be two years in arrears with his subscriptions may be erased from the list of members,

but such member may be re-admitted on giving a satisfactory explanation to the Council, and on payment of such arrears as the Council may determine.

At the meeting held in July, and at all subsequent meetings for the year, a list of the names of all those members who are in arrears with their annual subscriptions shall be exhibited in the Rooms of the Society. Members shall in all cases be informed that their names have been thus posted.

XVIII. Any member in arrears shall cease to receive the Society's publications, and shall not be entitled to any of the privileges of the Society until such arrears are paid.

Resignation of Members.

XIX. Members who wish to resign their membership of the Society are required to give notice in writing to the Honorary Secretaries, and are required to return all books or other property belonging to the Society, and to pay all arrears of subscriptions due to the Society.

Expulsion of Members.

XX. A majority of members present at any ordinary general meeting shall have power to expel an obnoxious member from the Society, provided that a resolution to that effect has been moved and seconded at the previous ordinary general meeting, and that due notice of the same has been sent in writing to the member in question, within a week after the meeting at which such resolution has been brought forward.

Honorary Members.

XXI. The Honorary Members of the Society shall be persons of eminent scientific attainments or distinguished promoters of the objects of the Society. Every person proposed as an Honorary Member must be recommended by the Council and elected by the Society. Honorary Members shall be exempted from payment of fees and contributions: they may attend the meetings of the Society, and they shall be furnished with copies of the publications of the Society, but they shall have no right to hold office, to vote.

The number of Honorary Members shall not at any one time exceed thirty, of whom at the time of election not more than ten (10) shall be domiciled in Australasia, and not more than three Honorary Members shall be elected in any one year.

Ordinary General Meetings.

XXII. An Ordinary General Meeting of the Royal Society, to be convened by public advertisement, shall take place at 8 p.m., on the first Wednesday in every month, during the last eight months of the year; subject to alteration by the Council with due notice.

Order of Business.

XXIII. At the Ordinary General Meetings the business shall be transacted in the following order, unless the Chairman specially decide otherwise :—

1—Minutes of the preceding Meeting.
2—New Members to enrol their names and be introduced.
3—Candidates for membership to be proposed.
4—Ballot for the election of new Members.
5—Business arising out of Minutes.
6—Communications from the Council.
8—Donations to be laid on the table and acknowledged.
9—Correspondence to be read.
10—Motions from last Meeting.
11—Notices of Motion for the next Meeting to be given in.
12—Papers to be read.
13—Discussion.
14—Notice of Papers for the next Meeting.

XXIV. At the Ordinary General Meetings of the Society nothing relating to its regulations or management, except as regards the election or ejection of members, shall be brought forward, unless the same shall have been announced in the notice calling the meeting, or be otherwise provided for in these Rules.

XXV. A special meeting of the Society may be called by the Council, provided that seven days' notice be given by advertisement, or shall be so called on a requisition signed by at least

twenty-five members of the Society, to consider any specia business thus notified.

Annual General Meeting—Annual Reports.

XXVI. The Annual General Meeting of the Society shall be held in May, to receive a Report from the Council on the State of the Society, and to elect Officers for the ensuing year. The Treasurer shall also at this meeting present the annual financial statement.

Admission of Visitors.

XXVII. Every ordinary member shall have the privilege of introducing two friends as visitors to an Ordinary General Meeting of the Society or its Sections, on the following conditions:—

1. That the name and residence of the visitors, together with the name of the member introducing them, be entered in a book at the time.
2. That they shall not have attended two consecutive meetings of the Society, or of any of its Sections in the current year.

The Council shall have power to introduce visitors irrespective of the above restrictions.

Council Meetings.

XXVIII. Meetings of the Council of Management shall take place on the last Wednesday in every month, and on such other days as the Council, may determine.

XXIX. The President or Hon. Secretaries, or any three Members of the Council, may call a meeting of the Council, provided that due notice of the same has been sent to each Member of the Council at least three days before such meeting.

Absence from Meetings of the Council—Quorum.

XXX. Any member of the Council absenting himself from three consecutive meetings of the Council, without giving a satisfactory explanation in writing, shall be considered to have vacated his office. No business shall be transacted at any meeting of the Council unless three members at least are present.

Duties of Secretaries.

XXXI. The Honorary Secretaries shall perform, or shall cause the Assistant Secretary to perform, the following duties :—

1. Conduct the correspondence of the Society and Council.
2. Attend the General Meetings of the Society and the meetings of the Council, to take minutes of the proceedings of such meetings, and at the commencement of such to read aloud the minutes of the preceding meeting.
3. At the Ordinary General Meetings of the members, to announce the presents made to the Society since their last meeting; to read the certificates of candidates for admission to the Society, and such original papers communicated to the Society as are not read by their respective authors, and the letters addressed to it.
4. To make abstracts of the papers read at the Ordinary General Meetings, to be inserted in the Minutes and printed in the Proceedings.
5. To edit the Transactions of the Society, and to superintend the making of an Index for the same.
6. To be responsible for the arrangement and safe custody of the books, maps, plans, specimens, and other property of the Society.
7. To make an entry of all books, maps, plans, pamphlets, etc., in the Library Catalogue, and of all presentations to the Society in the Donation Book.
8. To keep an account of the issue and return of books, &c., borrowed by members of the Society, and to see that the borrower, in every case, signs for the same in the Library Book.
9. To address to every person elected into the Society a printed copy of the Forms Nos. 2 and 3 (in the Appendix), together with a list of the members, a copy of the Rules, and a card of the dates of meetings; and to acknowledge all donations made to the Society.

10. To cause due notice to be given of all Meetings of the Society and Council.
11. To keep a list of the attendances of the members of the Council at the Council Meetings and at the ordinary General Meetings, in order that the same may be laid before the Society at the Annual General Meeting held in the month of May.

The Honorary Secretaries shall, by mutual agreement, divide the performance of the duties above enumerated.

The Honorary Secretaries shall, by virtue of their office, be members of all Committees appointed by the Council.

Contributions to the Society.

XXXII. Contributions to the Society, of whatever character, must be sent to one of the Hon. Secretaries, to be laid before the Council of Management. It will be the duty of the Council to arrange for promulgation and discussion at an Ordinary Meeting such communications as are suitable for that purpose, as well as to dispose of the whole in the manner best adapted to promote the objects of the Society.

XXXIII. The original copy of every paper communicated to the Society, with the illustrative drawings, shall become the property of the Society unless stipulation be made to the contrary; and authors shall not be at liberty, save by permission of the Council, to publish the papers they have communicated, until such papers, or abstracts of them, have appeared in the Journal or other publications of the Society.

XXXIV. If any paper of importance is communicated during the recess, the same may be ordered for publication by the Council without being read to the Society.

Management of Funds.

XXXV. The funds of the Society shall be lodged at a Bank named by the Council of Management. Claims against the Society, when approved by the Council, shall be paid by the Treasurer. All cheques shall be countersigned by a member of the Council.

**Money Grants.*

XXXVI. Grants of money in aid of scientific purposes from the funds of the Society—to Sections or to members—shall expire on the 1st of November in each year. Such grants, if not expended, may be re-voted.

XXXVII. Such grants of money to Committees and individual members shall not be used to defray any personal expenses which a member may incur.

Audit of Accounts.

XXXVIII. Two Auditors shall be appointed annually, at an Ordinary General Meeting, to audit the Treasurer's Accounts. The accounts as audited to be laid before the Annual Meeting in May.

Property of the Society to be vested in the President, &c.

XXXIX. All property whatever belonging to the Society shall be vested in the President, Vice-Presidents, Hon. Treasurer, and Hon. Secretaries for the time being, in trust for the use of the Society; but the Council shall have control over the disbursements of the funds and the management of the property of the Society.

Reports.

XL. It shall be the duty of the President, Vice-Presidents, Hon. Treasurer, and Honorary Secretaries to annually examine into and report to the Council upon the state of—

1. The Society's house and effects.
2. The keeping of the official books and correspondence.
3. The Library, including maps and drawings.
4. The Society's cabinets and collections.

Cabinets and Collections.

XLI. The keepers of the Society's cabinets and collections shall give a list of the contents, and report upon the condition of the same to the Council annually.

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*Applicants for money grants are required to supply the following information:—

1. The nature of the research and the scientific results expected to follow therefrom.
2. The amount asked for.
3. Whether any previous grant has been received from any source, and if so with what results.
4. Whether any portion of the grant is to be devoted to personal remuneration.
5. What apparatus (if any) of permanent value will be required.

Sections.

XLII. To allow those members of the Society who devote attention to particular branches of science fuller opportunities and facilities of meeting and working together with fewer formal restrictions than are necessary at the Ordinary General Meetings of the Society,—Sections or Committees may be established in the following branches of science :—

Section A.—Astronomy, Meteorology, Physics, Mathematics, and Mechanics.

Section B.—Chemistry and Mineralogy, and their application to the Arts and Agriculture.

Section C.—Geology and Palæontology.

Section D.—Biology, *i.e.* Botany and Zoology, including Entomology.

Section E.—Miscroscopical Science.

Section F.—Geography and Ethnology.

Section G.—Literature and the Fine Arts, including Architecture.

Section H.—Medical.

Section I.—Sanitary and Social Science and Statistics.

Section K.—Civil and Mechanical Engineering.

Section Committees—Card of Meetings.

XLIII. The first meeting of each Section shall be appointed by the Council. At that meeting the members shall elect their own chairman, Secretary, and a Committee of four; and arrange the days and hours of their future meetings. A card showing the dates of each meeting for the current year shall he printed for distribution amongst the members of the Society.

Membership of Sections.

XLIV. Only members of the Society shall have the privilege of joining any of the Sections.

Reports from Sections.

XLV. The Secretary of each Section shall keep minutes of its proceedings. The Chairman and the Secretary shall jointly prepare and forward to the Hon. Secretaries of the Society, on or

before the 21st December in each year, a report of the proceedings of the Section during that year, in order that the same may be laid before the Council.

Documents.

XLVI. The Honorary Secretaries and Honorary Treasurer shall see that all documents relating to the Society's property, the obligations given by members, the policies of insurance, and other securities shall be lodged in the Society's iron chest, the contents of which shall be inspected by the Council once in every year; a list of such contents shall be kept, and such list shall be signed by the President or one of the Vice-Presidents at the annual inspection.

Branch Societies.

XLVII. The Society shall have power to form Branch Societies in other parts of the State.

Library.

XLVIII. The members of the Society shall have access to, and shall be entitled to borrow books from the Library, under such regulations as the Council may think necessary.

Alteration of Rules.

XLIX. No alteration of, or addition to, the Rules of the Society shall be made unless carried at one Ordinary General Meeting, and confirmed at the next Annual General Meeting, at each of which twenty-five members at least must be present.

THE LIBRARY.

1. The Library shall be open for consultation and for the issue and return of books daily (except Saturday), from 9.30 a.m. to 1 p.m., and 2 to 6 p.m., and on Saturdays from 9·30 a.m. to 1·30 p.m.

2. The Library will not be open on public holidays.

3. No book shall be issued without being signed for in the Library Book.

4. Members are not allowed to have more than two volumes at a time from the Library, without special permission from one of the Honorary Secretaries, nor to retain a book for a longer period than fourteen days; but when a book is returned by a member it may be borrowed by him again, provided it has not been bespoken by any other member. Books which have been bespoken shall circulate in rotation, according to priority of application.

5. Scientific Periodicals and Journals will not be lent until the volumes are completed and bound.

6. Dictionaries, Encyclopædias, and other works of reference and cost, Atlases, Books and Illustrations in loose sheets, Drawings, Prints and unbound numbers of Periodicals and Works, Journals, Transactions and Proceedings of Societies or Institutions, Works of a Series, Maps or Charts, are not to be removed from the Library without the written order of the President or one of the Hon. Secretaries.

7. Members retaining books longer than the time specified shall be subject to a fine of sixpence per week for each volume.

8. The books which have been issued shall be called in by the Secretaries twice a year; and in the event of any book not being returned on those occasions, the member to whom it was issued shall be answerable for it, and shall be required to defray the cost of replacing the same.

9. No stranger shall be admitted to the Library except by the introduction of a member, whose name, together with that of the visitor, shall be inserted in a book kept for that purpose.

10. Members shall not lay the paper upon which the year writing on any Book or Map.

No tracings shall be made without express permission from the Hon. Secretaries.

Form No. 1.

ROYAL SOCIETY OF NEW SOUTH WALES.

Certificate of a Candidate for Election.

Name

Qualification or occupation

Address

being desirous of admission into the Royal Society of New South Wales, we, the undersigned members of the Society, propose and recommend him as a proper person to become a member thereof.

Dated this day of 190 .

FROM PERSONAL KNOWLEDGE.	FROM GENERAL KNOWLEDGE.

Signature of candidate

Date received 190 .

N.B.—This certificate must be signed by three or more members, to two of whom the candidate must be personally known. The candidate must be at least twenty-one years of age. This certificate has to be read at three ordinary general meetings of the Society.

Form No. 2.

ROYAL SOCIETY OF NEW SOUTH WALES.

The Society's House,

Sir, Sydney 190 .

I have the honour to inform you that you have this day been elected a member of the Royal Society of New South Wales, and I beg to forward to you a copy of the rules of the Society, a printed copy of an obligation, a list of members, and a card announcing the dates of meeting during the present session.

According to the Regulations of the Society (*vide* Rule No. 9), you are required to pay your admission fee of two guineas, and annual subscription of two guineas for the current year, before admission. You are also requested to sign and return the enclosed form of obligation at your earliest convenience.

I have, &c.,

To Hon Secretary.

Form No. 3.

ROYAL SOCIETY OF NEW SOUTH WALES.

I, the undersigned, do hereby engage that I will endeavour to promote the interests and welfare of the Royal Society of New South Wales, and to observe its Rules and By-laws, as long as I shall remain a member thereof.

Address Signed,

Date

Form No. 4.

List of Members, recommended by the Council under Rule IV., as Members of the New Council.

ROYAL SOCIETY OF NEW SOUTH WALES.

Date. ....

Present Council.	Persons recommended as Members of the New Council	
	President.	
	Vice-Presidents.	
	Hon. Treasurer.	
	Hon. Secretaries.	
	Members of Council.	

Any member of the Society not disqualified by Rules XVI., XVII., or XVIII., may be nominated for the position of President, Vice-President, Honorary Treasurer, Honorary Secretary, or Member of the Council, provided that his candidature shall have been notified to the Honorary Secretary or Secretaries under the hands of two qualified voters—such notification being countersigned by the nominee—at least fourteen days before the day appointed for the Annual General Meeting.

Form No. 5.

Balloting List for the Election of Officers and Council.

ROYAL SOCIETY OF NEW SOUTH WALES.

Date.........................

Council's recommendation under Rule IV. Proposed Members of the New Council.	Nomination by Ordinary Members.	Name of Nominators.
President.	President.	
Vice-Presidents.	Vice-Presidents.	
Hon. Treasurer.	Hon. Treasurer.	
Hon. Secretaries.	Hon. Secretaries.	
Members of Council.	Members of Council.	

NOTICE.

Members are particularly requested to communicate any change of address to the Hon. Secretaries, for which purpose this slip is inserted.

Corrected Address:

Name..

....

Titles, &c..

....

Address...

....

....

Date..........................

To the

Hon. Secretaries,

The Royal Society of N. S. Wales,

5 Elizabeth Street, Sydney.

LIST OF THE MEMBERS

OF THE

Royal Society of New South Wales.

P Members who have contributed papers which have been published in the Society's Transactions or Journal; papers published in the Transactions of the Philosophical Society are also included. The numerals indicate the number of such contributions.

‡ Life Members.

Elected.		
1877	P 5	Abbott, W. E., 'Abbotsford,' Wingen.
1895		Adams, J. H. M., Broughton Cottage, St. James' Rd., Waverley.
1890	P 2	Allan, Percy, M. Inst. C.E., Assoc. M. Am. Soc. C.E., Engineer-in-Charge, of Bridge Design, Public Works Department, Sydney.
1885		Allworth, Joseph Witter, Chief Surveyor, Lands Department, Sydney.
1898		Alexander, Frank Lee, c/o Messrs. Goodlet and Smith Ld., Cement Works, Granville.
1877		Anderson, H. C. L., M.A, Principal Librarian, Public Library of N. S. Wales, 161 Macquarie-street.
1899	P 1	Atkinson, A. A., Chief Inspector of Collieries, Department of Mines, Sydney.
1878		Backhouse, Alfred P., M.A., District Court Judge, 'Melita,' Elizabeth Bay.
1894	P 8	Baker, Richard Thomas, F.L.S., Curator, Technological Museum.
1900		Bale, Ernest, C.E,. Public Works Department.
1894		‡Balsile, George, 'Sandymount,' Dunedin, New Zealand.
1895	P 5	Bancroft, T. L., M.B. *Edin*, Deception Bay, viâ Burpengary, Brisbane, Queensland.
1896		Barff, H. E., M.A., Registrar, Sydney University.
1895	P 7	Barraclough, S. H., B.E., M.M.E., Assoc. M. Inst. C.E., Memb. Soc. Promotion Eng. Education, Lecturer in Engineering, Sydney University; p.r. 'Lansdowne,' 30 Bayswater Road, Darlinghurst.
1901		Bartholomew, Charles P, 361 George-street.
1894		Baxter, William Howe, Chief Surveyor Existing Lines Office, Railway Department, Bridge-street.
1898		Beale, Charles Griffin, 109 Pitt-street and Warrigal Club.
1877		Belfield, Algernon H., 'Eversleigh,' Dumaresq.
1876		Benbow, Clement A., 48 College-street.
1900		Bender, Ferdinand, Accountant and Auditor, 21 Elizabeth-street, North.
1869	P 2	Bensusan, S. L, Equitable Building, George-st., Box 411 G.P.O.
1895		Bensusan, A. J., A.R.S.M., F.C.S., Laboratory, 12 O'Connell-st.
1901		Birks, Lawrence, B.Sc., Assoc. M. Inst. C.E., A.M.I.E.E., F.G.S., 133 Macquarie-street.
1888		‡Blaxland, Walter, F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Mount Barker, South Australia.

Elected		
1893		Blomfield, Charles E., B.C.E. *Melb.*, Public Works Department Sydney.
1879		Blunno, Michele, Licenziato in Science (Roma), Government Viticultural Expert, Department of Agriculture, Sydney.
1879		‡Bond, Albert, 131 Bell's Chambers, Pitt-street.
1895	P 1	Boultbee, James W., Superintendent of Public Watering Places and Artesian Boring, Department of Lands.
1891		Bowman, Archer S., B.E., 'Keadue,' Elizabeth Bay Road.
1893		Bowman, John, Assoc. M. Inst. C.E., Tramway Construction Branch, Public Works Department.
1893		Bowman, Reginald, M.B. et Ch. M. *Edin.*, M.R.C.S. *Eng.*, 261 Elizabeth-street and George-street, Parramatta.
1876		Brady, Andrew John, Lic. K. & Q. Coll. Phys. *Irel.*, Lic. R. Coll. Sur. *Irel.* 3 Lyons' Terrace, Hyde Park.
1891		Brennand, Henry J. W., B.A., M.B., Ch.M. Syd. Univ., 203 Macquarie-street.
1902		Brereton, Victor Le Gay, Solicitor, Tattersall's Chambers, Hunter-st.; p.r. 'Osgathorpe,' Gladesville.
1878		‡Brooks, Joseph, F.R.A.S., F.R.G.S., 'Hope Bank,' Nelson-street, Woollahra.
1876		Brown, Henry Joseph, Solicitor, Newcastle.
1891		Bruce, John Leck, Technical College, Sydney.
1898		Burfitt, W. Fitzmaurice, M.B., Ch.M. *Syd.*, B.A., B.Sc., 311 Glebe Road, Glebe Point.
1891	P 4	Burge, Charles Ormsby, M. Inst. C.E., Principal Assistant Engineer, Railway Construction, p.r. 'Fitz Johns,' Alfred-st. N., North Sydney.
1890		Burne, Dr. Alfred, Dentist, 1 Lyons' Terrace, Liverpool-street.
1880		Bush, Thomas James, M. Inst. C.E., Engineer's Office, Australian Gas-Light Company, 163 Kent-street.
1876		Cadell, Alfred, Coramba, viâ South Grafton.
1902		Calder, Robert A., Dentist, 448 Castlereagh-street.
1897		Callender, James Ormiston, Consulting Electrical Engineer, 20 St. James' Court, Buckingham Gate, London S.W.
1894		Cameron, Alex. Mackenzie, Walgett.
1899		Cameron, R. B., Secretary A.M.P. Society, 87 Pitt-street.
1900		Canty, M., 'Rosemont,' 13 York-street, Wynyard Square.
1876		Cape, Alfred J., M.A. *Syd.*, 'Karoola,' Edgecliffe Rd., Edgecliffe.
1897	P 1	Cardew, John Haydon, Assoc. M. Inst. C.E., L.S., 75 Pitt-street.
1901		Card, George William, A.R.S.M., F.G.S., Curator and Mineralogist to the Geological Survey, N.S.W. Department of Mines.
1891		Carment, David. F.I.A. *Gt. Brit. & Irel*, F.F.A. *Scot.*, Australian Mutual Provident Society, 87 Pitt-street.
1879	P 1	‡Chard, J. S, Licensed Surveyor, Armidale.
1878		Chisholm, Edwin, M.R.C.S. *Eng.*, L.S.A. *Lond.*, 82 Darlinghurst Road.
1885		Chisholm, William, M.D., *Lond.*, 139 Macquarie-street, North.
1888		Clubbe, C. P. B., L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 195 Macquarie-st.
1896	P 1	Cook, W. E., M.C.E. *Melb.* Univ., M. Inst. C.E., District Engineer, Water and Sewerage Department, North Sydney.
1876		Codrington, John Frederick, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, L.R.C.P. *Edin.*, 'Winwood,' Wahroonga.

Elected		
1893		Cohen, Algernon A., M.B., M.D. *Aberd.*, M.R.C.S. *Eng.*, 61 Darlinghurst Road.
1876		Colyer, J. U. C., Australian Gas-Light Co., 163 Kent-street.
1856		Comrie, James, 'Northfield,' Kurrajong Heights, viâ Richmond.
1882		Cornwell, Samuel, Australian Brewery, Bourke-st., Waterloo.
1891		Coutie, W. H., M.B., Ch. B. Univ. *Melb.*, 'Warminster,' Canterbury Road, Petersham.
1892	P 1	Cowdery, George R., Assoc. M. Inst. C.E., Engineer for Tramways, 72A Phillip-st., p.r. 'Glencoe,' Torrington Rd., Strathfield.
1886		Crago, W. H., M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 16 College-street, Hyde Park.
1869		Creed, The Hon. J. Mildred, M.L.C., M.R.C.S. *Eng.*, L.R.C.P. *Edin.*, 195 Elizabeth-street.
1870		Croudace, Thomas, Lambton.
1891	P 5	Curran, Rev. J. Milne, Lecturer in Geology, Technical College, Sydney.
1875		Dangar, Fred. H., c/o Messrs. Dangar, Gedye, & Co., Mercantile Bank Chambers, Margaret-street.
1893		Dare, Henry Harvey, M.E., Assoc. M. Inst. C.E., Roads and Bridges Branch, Public Works Department.
1876	P 3	Darley, Cecil West, M. Inst. C.E., c/o The Agent General, Westminster Chambers, 9 Victoria-street, London, S.W.
1877		Darley, The Hon. Sir Frederick, G.C.M.G., B.A., Chief Justice, Supreme Court.
1886	P 15	David, T. W. Edgeworth, B.A., F.R.S., F.G.S., Professor of Geology and Physical Geography, Sydney University, Glebe. *Vice-President.*
1892	P 1	Davis, Joseph, M. Inst. C.E., Under Secretary, Department of Public Works.
1878		Dean, Alexander, J.P., 42 Castlereagh-street, Box 409 G.P.O.
1885	P 2	Deane, Henry, M.A., M. Inst. C.E., Engineer-in-Chief for Railways, Railway Construction Branch, Public Works Department; p.r. 'Blanerne,' Wybalena Road, Hunter's Hill. *Vice-President.*
1877		Deck, John Feild, M.D. Univ. *St. And.*, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 203 Macquarie-st.; p.r. 92 Elizabeth-st., Ashfield.
1899	P 1	De Coque, J. V., Public Works Department, Sydney.
1894		Dick, James Adam, B.A. *Syd.*, M.D., C.M. *Edin.*, 'Catfoss,' Belmore Road, Randwick.
1875	P 12	Dixon, W. A., F.C.S., Fellow of the Institute of Chemistry of Great Britain and Ireland, 97 Pitt-street.
1880		Dixson, Thomas, M.B. *Edin.*, Mast. Surg. *Edin.*, 287 Elizabeth-street, Hyde Park.
1879		Docker, Wilfred L., 'Nyrambla,' Darlinghurst Road.
1876		Docker, Ernest B., M.A. *Syd.*, District Court Judge, 'Eltham,' Edgecliffe Road.
1899		Duckworth, A., A.M.P. Society, 87 Pitt-st.; p.r. 'Trentham,' Woollahra.
1873	P 1	Du Faur, F.R.G.S., Exchange Buildings, Pitt-street.

Elected		
1894		Edgell, Robert Gordon, Roads and Bridges Office, Wollombi.
1896		Edwards, George Rixon, Resident Engineer, Roads and Bridges Branch, Crookwell.
1901		Enright, Walter J., B.A. *Syd.*, Solicitor, 'Fairy Lawn,' West Maitland.
1879	P 4	Etheridge, Robert, Junr., J.P., Curator, Australian Museum; p.r. 21 Roslyn-street, Darlinghurst.
1876		Evans, George, Fitz Evan Chambers, Castlereagh-street.
1892		Everett, W. Frank, Roads and Bridges Office, Muswellbrook.
1896		Fairfax, Charles Burton, *S. M. Herald* Office, Hunter-street.
1877		‡Fairfax, Edward Ross, *S. M. Herald* Office, Hunter-street.
1896		Fairfax, Geoffrey E., *S. M. Herald* Office, Hunter-street.
1868		Fairfax, Sir James R., Knt., *S. M. Herald* Office, Hunter-st.
1887		Faithfull, R. L., M.D. *New York* (Coll. Phys. & Surg.) L.R.C.P., L.S.A. *Lond.*, 18 Wylde-street.
1889		Farr, Joshua J., J.P., 'Cora Lynn,' Addison Rd., Marrickville.
1897		Fell, David, C.A.A., Public Accountant, Equitable Building, George-street.
1881		Fiaschi, Thos., M.D., M.Ch., Univ. *Pisa*, 149 Macquarie-street.
1891		Firth, Thomas Rhodes, M. Inst. C.E., 'Glenevin,' Arncliffe.
1891		Fitzgerald, Robert D., C.E., Roads and Bridges Branch, Department of Public Works, Sydney; p.r. Alexandra-st., Hunter's Hill.
1888		Fitzhardinge, Grantly Hyde, M.A. *Syd.*, District Court Judge, 'Red Hill,' Beecroft, Northern Line.
1894		Fitz Nead, A. Churchill, Lands Department, Lismore.
1900		‡Flashman, James Froude, M.D. *Syd.*, 'Totnes,' Temple-street, Petersham.
1879		‡Foreman, Joseph, M.R.C.S. *Eng.*, L.R.C.P. *Edin.*, 141 Macquarie-street.
1881		Foster, The Hon. W. J., K.C., 'Thurnby,' Enmore Road, Newtown.
1899		French, J. Russell, General Manager, Bank of New South Wales, George-street.
1881		Furber, T. F., Trignometrical Service; p.r. 'Tennyson House,' 145 Victoria-street.
1899		Garran, R. R., M.A., C.M.G., Wigram Chambers, Phillip-street.
1876		George, W. R., 318 George-street.
1879		Gerard, Francis, 'Clandulla,' Goulburn.
1896		Gibson, Frederick William, District Court, Judge 'Grasmere,' Stanmore Road.
1891		Gill, Robert J., Public Works Department, Moruya.
1876	P 4	Gipps, F. B., C.E., 'Elmly,' Mordialloc, Victoria.
1883		Goode, W. H., M.A., M.D., Ch.M., Diplomate in State Medicine *Dub.*; Surgeon Royal Navy; Corres. Mem. Royal Dublin Society; Mem. Brit. Med. Assoc.; Lecturer on Medical Jurisprudence, University of Sydney, 159 Macquarie-st.
1859		Goodlet, John H., 'Canterbury House,' Ashfield.
1896		Gollin, Walter J., Australian Club.

Elected		
1897		Gould, Major The Hon. Albert John, Senator, Holt's Chambers, 121 Pitt-street; p.r. 'Eynesbury,' Edgecliff.
1886		Graham, Sir James, Knt., M.A., M.D., M.B., C.M., *Edin.*, 188 Liverpool-street.
1891	P 1	Grimshaw, James Walter, M. Inst. C.E., M. I. Mech. E., &c., Australian Club, Sydney.
1899	P 1	Gummow, Frank M., M.C.E., Assoc. M. Inst. C.E., Vickery's Chambers, Pitt-street.
1877		Gurney, T. T., M.A. *Cantab.*, Professor of Mathematics, Sydney University; p.r. 'Clavering,' French's Forest Road, Manly.
1891	P 4	Guthrie, Frederick B., F.I.C., F.C.S., Department of Agriculture, Sydney.
1900		Hadley, Arthur, F.C.S., Standard Brewery, Sydney.
1880	P 1	Halligan, Gerald H., F.G.S., 'Riversleigh,' Hunter's Hill.
1899		Halloran, A., B.A., LL.B. 20 Castlereagh-street.
1892		Halloran, Henry Ferdinand, L.S., Scott's Chambers, 94 Pitt-st.
1901		Hamilton, John William, C.E., 'Herrickville,' Alt-st., Ashfield.
1887	P 6	Hamlet, William M., F.I.C., F.C.S., Member of the Society of Public Analysts; Government Analyst, Health Department, Macquarie-street North. *Vice-President.*
1882		Hankins, George Thomas, M.R.C.S., *Eng.*, 'St. Romans,' Allison Road Randwick.
1881		‡Harris, John, 'Bulwarra,' Jones-street Ultimo.
1877	P 18	‡Hargrave, Lawrence, J.P., Woollahra Point.
1899		Harper, H. W., Assoc. M. Inst. C.E., Equitable Buildings, George-st.
1844		Haswell, William Aitcheson, M.A., D.Sc., F.R.S., Professor of Zoology and Comparative Anatomy, University, Sydney; p.r., 'Mimihu,' Woollahra Point.
1899		Hawker, Herbert, Demonstrator in Physiology, University of Sydney; p.r. 1 Northumberland Avenue, Petersham.
1900		Hawkins, W. E., Solicitor, 88 Pitt-street.
1890	P 2	Haycroft, James Isaac, M.E. Queen's Univ. *Irel.*, Assoc. M. Inst. C.E., Assoc. M. Can. Soc. C.E., Assoc. M. Am. Soc. C.E., M.M. & C.E., M. Inst. C.E. I., L.S., 'Fontenoy,' Ocean-street, Woollahra.
1891		Hedley, Charles, F.L.S., Assistant in Zoology, Australian Museum, Sydney.
1900		Helms, Richard, Experimentalist, Department of Agriculture.
1902		Hennessy, John Francis, Architect, City Chambers, 243 Pitt-st.
1899		Henderson, J., Manager, City Bank of Sydney, Pitt-street.
1899		Henderson, S., M.A., Assoc. M. Inst. C.E., Equitable Building, George-street.
1884		Henson, Joshua B., Assoc. M. C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1891		Hickson, Robert R. P., M. Inst. C.E., Chairman Harbour Trust, Sydney; p.r. 'The Pines,' Bondi.
1876	P 2	Hirst, George D., F.R.A.S., 379 George-street.
1896		Hinder, Henry Critchley, M.B., C.M. *Syd.*, Elizabeth-st., Ashfield.
1892		Hodgson, Charles George, 157 Macquarie-street.
1901		Holt, Thomas S., 'Holwood,' Victoria-street, Ashfield.
1891	P 2	Houghton, Thos. Harry, M. Inst. C.E., M. I. Mech. E., 63 Pitt-street.
1879		Houison, Andrew, B.A., M.B., C.M. *Edin.*, 47 Phillip-street.
1891	P 1	How, William F., M. Inst. C.E., M. I. Mech. E., Wh. Sc., Mutual Life Buildings, George-street.

Elected		
1877		Hume, J. K., 'Beulah,' Campbelltown.
1894	P 2	Hunt, Henry A., F. R. Met. Soc., First Meteorological Assistant, Sydney Observatory.
1894		Jamieson, Sydney, B.A., M.B., M.R.C.S., L.R.C.P., 189 Liverpool-street, Hyde Park.
1900		Jarman, Arthur, A.R.S.M., Demonstrator, University of Sydney.
1884		Jenkins, Edward Johnstone, M.A., M.D. *Oxon.*, M.R.C.P., M.R.C.S., L.S.A. *Lond.*, 213 Macquarie-street, North.
1887		Jones, George Mander, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 'Viwa,' Burlington Road, Homebush.
1884		Jones, Llewellyn Charles Russell, Solicitor, Sydney Chambers, 130 Pitt-street.
1867		Jones, P. Sydney, M.D. *Lond.*, F.R.C.S. *Eng.*, 16 College-street, Hyde Park; p r. 'Llandilo,' Boulevard, Strathfield.
1876		Jones, Richard Theophilus, M.D. *Syd.*, L.R.C.P. *Edin.*, 'Cader Idris,' Ashfield.
1876	P 2	Josephson, J. Percy, Assoc. M. Inst. C E., Stephen Court, 81 Elizabeth-street, p.r. 'Moppity,' George-street, Dulwich Hill.
1878		Joubert, Numa, Hunter's Hill.
1883		Kater, The Hon. H. E., J.P., M.L.C., Australian Club.
1873		Keele, Thomas William, M. Inst. C.E., Harbours and Rivers Branch, Public Works Department.
1877		Keep, John, Broughton Hall, Leichhardt.
1894		Kelly, Walter Macdonnell, L.R.C P., L R.C.S. *Edin.*, L.F.P.S. *Glas.*, 265 Elizabeth-street.
1887		Kent, Harry C., M.A., Bell's Chambers, 129 Pitt-street.
1898		Kerry, Charles H., J.P., 310 George-street.
1901		Kidd, Hector, 'Craig Lea,' 15 Mansfield-street, Glebe Point.
1892	P 3	Kiddle, Hugh Charles, F. R. Met. Soc., Public School, Seven Oaks, Smithtown, Macleay River.
1891		King, Christopher Watkins, Assoc. M. Inst. C.E., L.S., Assistant Engineer, Harbours and Rivers Department, Newcastle.
1874		King, The Hon. Phillip G., M.L.C., 'Banksia,' William-street, Double Bay.
1896		King, Kelso, 120 Pitt-street.
1892		Kircaldie, David, Commissioner, New South Wales Government Railways, Sydney.
1878		Knaggs, Samuel T., M.D. *Aberdeen.*, F.R.C.S. *Irel.*. 5 Lyons' Terrace, Hyde Park.
1881	P 16	Knibbs, G. H., F.R.A.S., Lecturer in Surveying, University of Sydney; p.r. 'Avoca House,' Denison Road, Petersham. *Hon. Secretary.*
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Rose Bay.
1878		Kyngdon, F. B., F.R.M.S. *Lond.*, Deanery Cottage, Bowral.
1874		Lenehan, Henry Alfred, F.R.A.S., Sydney Observatory.
1901		Lindeman, Charles F., Wine Merchant, Jersey Rd., Strathfield.
1883		Lingen, J. T., M.A. *Cantab.*, 167 Phillip-street.

Elected		
1901		Little, Robert, 'The Hermitage,' Double Bay.
1872	P 51	Liversidge, Archibald, M.A. *Cantab.*, LL.D., F.R.S., Hon. F.R.S. *Edin.*; Assoc. Roy. Sch. Mines, *Lond.*; F.C.S., F.G.S., F.R.G.S.; Fel. Inst. Chem. of Gt. Brit. and Irel.; Hon. Fel. Roy. Historical Soc. *Lond*; Mem. Phy. Soc. *Lond.*; Mineralogical Society, *Lond.*; Edin. Geol. Soc.; Mineralogical Society, *France*; Corr. Mem. Edin. Geol. Soc.; New York Acad. of Sciences; Roy. Soc., *Tas.*; Roy. Soc., *Queensland*; Senckenberg Institute, *Frankfurt*; Society d' Acclimat., *Mauritius*; Foreign Corr. Indiana Acad. of Sciences; Hon. Mem. Roy. Soc., *Vict.*; N. Z. Institute; K. Leop. Carol. Acad., *Halle a/s*; Professor of Chemistry in the University of Sydney, The University, Glebe; p.r. 'The Octagon,' St. Mark's Road, Darling Point. *Vice-President.*
1878		Low, Hamilton, 'Lillington.' Cambridge-street, Stanmore.
1892		MacCarthy, Charles W., M.D., F.R.C.S. *Irel.*; 223 Elizabeth-street, Hyde Park.
1887		MacCormick, Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 125 Macquarie-street, North.
1887		MacCulloch, Stanhope H., M.B., C.M. *Edin.*, 24 College-street.
1874		M'Cutcheon, John Warner, 'Mayville,' Wallis-st., Woollahra.
1892		McDonagh, John M., B.A., M.D., M.R.C.P. *Lond.*, F.R.C.S. *Irel.*, 173 Macquarie-street, North.
1897		MacDonald, C. A., C.E., 63 Pitt-street.
1878		MacDonald, Ebenezer, J.P., c/o Perpetual Trustee Co. Ld., 2 Spring-street.
1868		MacDonnell, William J., F.R.A.S., 15 Post Office Chambers, Pitt-street.
1877		MacDonnell, S., 121 Pitt-street.
1891		McDouall, Herbert Crichton, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, D.P.H. *Camb.*, Hospital for Insane, Callan Park, Rozelle.
1900		McKay, G. A., Chief Mining Surveyor, Department of Mines, Sydney.
1891		McKay, R. T., L.S., Sewerage Construction Branch, Public Works Department.
1893		McKay, William J. Stewart, B.Sc., M.B., Ch.M., Cambridge-street, Stanmore.
1876		Mackellar, The Hon. Charles Kinnaird, M.L.C., M.B., C.M. *Glas.*, Equitable Building, George-street.
1876		Mackenzie, Rev. P. F., The Manse, Johnston st., Annandale.
1880	P 7	M'Kinney, Hugh Giffin, M.E. Roy. Univ. *Irel.*, M. Inst. C. E., Exchange, 56 Pitt-st.; p.r. 'Dilkhusha,' Fuller's Road, Chatswood.
1876		MacLaurin, The Hon. Henry Norman, M.L.C., M.A., M.D. *Edin.*, L.R.C.S. *Edin.*, LL.D. Univ. *St. Andrews*, 155 Macquarie-st.
1901		McMaster, Colin J., Chief Commissioner of Western Lands, p.r. 'Monomie,' Longueville.
1901		McMillan, Robert, 129 Macquarie-street.
1894		McMillan, Sir William, 'Logan Brae,' Waverley.
1900		MacTaggart, A. H., D.D.S. *Phil.* U.S.A., King and Phillip-sts.
1899		MacTaggart, J. N. C., B.E. *Syd.*, 16 Lugar-street, Waverley.
1882	P 1	Madsen, Hans. F., 'Hesselmed House,' Queen-st., Newtown.

Elected		
1883	P 8	Maiden, J. Henry, J.P., F.L.S., Government Botanist and Director, Botanic Gardens, Sydney. *Hon. Secretary.*
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1877		Mann, John F., 'Kerepunu,' Neutral Bay.
1876		Manning, Frederic Norton, M.D. Univ. *St. And.*, M.R.C.S. *Eng.*, L.S.A. *Lond.*, Australian Club.
1869		Mansfield, G. Allen, Martin Chambers, Moore-street.
1897		Marden, John, B.A., M.A., LL.B., Univ. *Melb.*, LL.D. Univ. *Syd.*, Principal, Presbyterian Ladies' College, Sydney.
1875	P 13	Mathews, Robert Hamilton, L.S., Assoc. Mem. Soc. d'Anthrop. de Paris; Cor. Mem. Anthrop. Soc., Washington, U.S.A.; Cor. Mem. Roy. Geog. Soc. Aust., Queensland; 'Carcuron,' Hassall street, Parramatta.
1888		Megginson, A. M., M.B., C.M. *Edin.*, 147 Elizabeth-street.
1896	P 5	Merfield, Charles J., F.R.A.S., Railway Construction Branch, Public Works Department; p.r. 'Branville,' Green Bank-street, Marrickville.
1887		Miles, George E., L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, The Hospital, Rydalmere, near Parramatta.
1878		Milford, F., M.D. *Heidelberg*, M.R.C.S. *Eng.*, 231 Elizabeth-st.
1882		Milson, James, 'Elamang,' North Shore.
1881	P 3	Mingaye, John C. H., F.I.C., F.C.S., Assayer and Analyst to the Department of Mines, Government Metallurgical Works, Clyde; p.r. Campbell-street, Parramatta.
1856	P 7	Moore, Charles, F.R.B.S., C.M.Z.S., Australian Club; p.r. 6 Queen-street, Woollahra.
1879		Moore, Frederick H., Illawarra Coal Co., Gresham-street.
1875		Moir, James, 58 Margaret-street.
1877	P 1	Morris, William, Fel. Fac. Phys. and Surg. *Glas.*, F.R.M.S. *Lond.*, c/o Mr. W. J. Munro, City Mutual Chambers, Hunter-street.
1882		Moss, Sydney, 'Kaloola,' Kirribilli Point, North Shore.
1877		‡Mullins, Josiah, F.R.G.S., 'Tenilba,' Burwood.
1879		Mullins, John Francis Lane, M.A. *Syd.*, 'Killountan,' Challis Avenue, Pott's Point.
1887		Munro, William John, B.A., M.B., C.M., M.D. *Edin.*, M.R.C.S. *Eng.*, 213 Macquarie-street; p.r. 'Forest House,' 182 Pyrmont Bridge Road, Forest Lodge.
1898		Murray, Lee, M.C.E. *Melb.*, Assoc. M. Inst. C.E., 16 O'Connell-street.
1876		Myles, Charles Henry, 'Dingadee,' Burwood.
1893		Nangle, James, Architect, Australia-street, Newtown.
1901		Newton, Roland G., 'Northleigh,' Union-street, North Sydney.
1891		‡Noble, Edwald George, 21 Norfolk-street, Paddington.
1878		Norton, The Hon. James, M.L.C., LL.D., Solicitor, 2 O'Connell-street; p.r. 'Ecclesbourne,' Double Bay.
1893		Noyes, Edward, C.E., c/o Messrs. Noyes Bros., 109 Pitt-street.
1896		Onslow, Lt. Col. James William Macarthur, Camden Park, Menangle.

Elected		
1875		O'Reilly, W. W. J., M.D., M.Ch., Q. Univ. *Irel.*, M.R.C.S. *Eng.*, 197 Liverpool-street.
1883		Osborne, Ben. M., J.P., 'Hopewood,' Bowral.
1891		Osborn, A. F., Assoc. M. Inst. C.E., Public Works Department, Cowra.
1880		Palmer, Joseph, 96 Pitt-st.; p.r. Kenneth-st., Willoughby.
1878		Paterson, Hugh, 197 Liverpool-street, Hyde Park.
1901		Peake, Algernon, 25 Prospect Road, Ashfield.
1899		Pearse, W., Union Club; p.r. Moss Vale.
1877		Pedley, Perceval R., 227 Macquarie-street.
1877		Perkins, Henry A., c/o Perpetual Trustee Co. Ld., 2 Spring-st.
1899		Peterson, T. T., Associate Sydney Institute of Public Accountants, 85 Womerah Avenue.
1876		Pickburn, Thomas, M.D., C.M. *Aberdeen*, M.R.C.S. *Eng.*, 22 College-street.
1879	P 5	Pittman, Edward F., Assoc. R.S.M., L.S., Government Geologist, Department of Mines.
1899		Plummer, John, 'Northwood,' Lane Cove River, Box 413 G.P.O.
1881		Poate, Frederick, Lands Office, Moree.
1879		Pockley, Thomas F. G., Commercial Bank, Singleton.
1887		Pollock, James Arthur, B.E. Roy. Univ. *Irel.*, B.Sc., *Syd.*, Professor of Physics, Sydney University.
1901		Pollitt, J. C. T., Analytical Chemist, Cooperative Wholesale Society Ld., Alexandria, Sydney.
1891		Poole, William, Junr., B.E. *Syd.*, Assoc. M. Inst. C.E., F.G.S., L.S., B. H. Proprietary Co. Ld., Port Pirie, South Australia; p.r. 87 Pitt-street, Redfern.
1896		Pope, Roland James, B.A. *Syd.*, M.D., C.M., F.R.C.S. *Edin.*, Ophthalmic Surgeon, 235 Macquarie-street.
1897	P 1	Portus, A. B., Assoc. M. Inst. C.E., Superintendent of Dredges, Public Works Department.
1893		Purser, Cecil, B.A., M.B., Ch.M. *Syd.*, 'Valdemar,' Boulevard, Petersham.
1901	P 1	Purvis, J. G. S., Water and Sewerage Board, 341 Pitt-street.
1899	P 1	Rae, J. L. C., Manager Sydney Harbour Collieries Ltd.; p.r. 'Strathmore,' Ewenton-street, Balmain.
1900		Ralston, J. T., Solicitor, 86 Pitt-street.
1865	P 1	‡Ramsay, Edward P., LL.D. Univ. St. And., F.R.S.,E., F.L.S., 8 Palace-street, Petersham.
1901		Raymond, Robert S., Brewer, Leichhardt.
1881	P 3	Rennie, Edward H., M.A. *Syd.*, D.Sc. *Lond.*, Professor of Chemistry, University, Adelaide.
1890		Rennie, George E., B.A. *Syd.*, M.D. *Lond.*, M.R.C.S. *Eng.*, 40 College-street, Hyde Park.
1870		Renwick, The Hon. Sir Arthur, Knt., M.L.C., B.A. *Syd.*, M.D., F.R.C.S. *Edin.*, 295 Elizabeth-street.
1893	P 1	Roberts, W. S. de Lisle, C.E., Sewerage Branch, Public Works Department, 5 Cumberland-street, Dawes Point.
1885		Rolleston, John C., Assoc. M. Inst. C.E., Harbours and Rivers Branch, Public Works Department.

Elected		
1897		Ronaldson, James Henry, Mining Engineer, 76 Pitt-street.
1892		Rossbach, William, Assoc. M. Inst. C.E., Chief Draftsman, Harbours and Rivers Branch, Public Works Department.
1884		Ross, Chisholm, M.D. *Syd.* M.B., C.M. *Edin.*, Hospital for the Insane, Callan Park, Rozelle.
1895		Ross, Colin John, B.Sc., B.E., Assoc. M. Inst. C.E., Borough Engineer, Town Hall, North Sydney.
1895	P 1	Ross, Herbert E., Consulting Mining Engineer, Equitable Building, George-street.
1882		Rothe, W. H., Colonial Sugar Co., O'Connell-st., and Union Club.
1894		Rowney, George Henry, Assoc. M. Inst. C.E., Sewerage Construction Public Works Department; p.r. 'Maryville,' Ben Boyd Road, Neutral Bay.
1864	P 67	Russell, Henry C., B.A. *Syd.*, C.M.G., F.R.S., F.R.A.S., F. R. Met. Soc. Hon. Memb. Roy. Soc. South Australia, Government Astronomer, Sydney Observatory. *President.*
1897		Russell, Harry Ambrose, B.A., Solicitor, c/o Messrs. Sly and Russell, 379*b* George-street; p.r. 'Mahuru,' Milton-street, Ashfield.
1893		Rygate, Philip W., M.A., B.E. *Syd.*, Assoc. M. Inst. C.E., Phœnix Chambers, 158 Pitt-street.
1899		Schmidlin, F., 44 Elizabeth-street, Sydney.
1892	P 1	Schofield, James Alexander, F.C.S., A.R.S.M. University, Sydney.
1856	P 1	‡Scott, Rev William, M.A. *Cantab.*, Kurrajong Heights.
1886		Scott, Walter, M.A. *Oxon.*, Professor of Greek, University, Sydney.
1877	P 4	Selfe, Norman, M. Inst. C.E., M. I. Mech. E., Victoria Chambers, 279 George-street.
1890	P 1	Sellors, R. P., B.A. *Syd.*, F.R.A.S., Trigonometrical Service, Lands Department.
1891		Shaw, Percy William, Assoc. M. Inst. C.E., Resident Engineer for Tramway Construction; p.r. 'Epcombs,' Miller-street, North Sydney.
1883	P 3	Shellshear, Walter, M. Inst. C.E., Divisional Engineer, Railway Department, Goulburn.
1900		Simpson, R. C., Demonstrator of Physics, Sydney University.
1882		Sinclair, Eric, M.D., C.M. Univ. *Glas.*, Hospital for the Insane, Gladesville.
1893		Sinclair, Russell, M. I. Mech. E. &c., Consulting Engineer, Alliance Chambers, 97 Pitt-street.
1884		Skirving, Robert Scot, M.B., C.M. *Edin.*, Elizabeth-street, Hyde Park.
1891	P 2	Smail, J. M., M. Inst. C.E., Chief Engineer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1893	P 24	Smith, Henry G., F.C.S., Technological Museum, Sydney.
1874	P 1	‡Smith, John McGarvie, 89 Denison-street, Woollahra.
1875		Smith, Robert, M.A. *Syd.*, Marlborough Chambers, 2 O'Connell-street.
1899		Smith, R. Greig, M.Sc., *Dun.*, B.Sc., *Edin.*, Macleay Bacteriologist, 'Otterburn,' Double Bay.
1898		Smith, S. Hague, Colonial Mutual Fire Insurance Co., 78 Pitt-st.

Elected		
1886		Smith, Walter Alexander, M. Inst. C.E., Roads, Bridges and Sewerage Branch, Public Works Department, N. Sydney.
1896		Smyth, Selwood, Harbours and Rivers Branch, Public Works Department.
1896		Spencer, Walter, M D. *Brux.*, 13 Edgeware Road, Enmore.
1892	P 1	Statham, Edwyn Joseph, Assoc. M. Inst. C.E., Cumberland Heights, Parramatta.
1889		Stephen, Arthur Winbourn, L.S., 12—14 O'Connell-street.
1891		Stilwell, A. W., Assoc. M. Inst. C.E., Public Works Depart., Sydney,
1900		Stewart, J. D., M.R.C.V.S., Government Veterinary Surgeon. Department of Mines and Agriculture; p r. Cowper-street, Randwick.
1883	P 8	Stuart, T. P. Anderson, M.D., LL.D. Univ. *Edin.*, Professor of Physiology, University of Sydney; p.r. 'Lincluden,' Fairfax Road, Double Bay.
1901		Süssmilch, C. A., Technical College, Sydney.
1893		‡Taylor, James, B.Sc., A.R.S.M., Adderton Road, Dundas.
1899		Teece, R., F.I.A., F.F.A., Actuary, A.M.P. Society, 87 Pitt-st.
1862	P 19	Tebbutt, John, F.R.A.S., Private Observatory. The Paninsula, Windsor, New South Wales.
1896		Thom, James Campbell, Solicitor for Railways; p.r. 'Camelot,' Forest Road, Bexley.
1896		Thom, John Stuart, Solicitor, Athenæum Chambers, 11 Castlereagh-street; p.r. Wollongong Road, Ardcliffe.
1878		Thomas, F. J., Hunter River N.S.N. Co . Sussex-street.
1879		Thomson, Dugald, M.H.R., 'Wyreepi,' Milson's Point.
1875		Thompson, Joseph, 159 Brougham-street, Woolloomooloo.
1885	P 2	Thompson, John Ashburton, M.D. *Brux.*, D.P.H. *Camb.*, M.R.C.S. *Eng.*, Health Department, Macquarie-street.
1896		Thompson, Capt. A. J. Onslow, Camden Park, Menangle.
1898		Thow, Sydney, General Manager, The Hercules Gold and Silver Mining Co., Mount Read, Tasmania.
1892		Thow, William, M. Inst. C.E., M. I. Mech. E., Locomotive Department, Eveleigh.
1886	P 5	Threlfall, Richard, M.A. *Cantab.*, Hagley Road, Edgebaston, Birmingham.
1888		Thring, Edward T., F.R.C.S. *Eng.*, L.R.C P. *Lond.*, 225 Macquarie-street.
1894		Tidswell, Frank, M.B., M.Ch., D.P.H., Health Department, Sydney
1876		Toohey, The Hon. J. T., M.L.C., 'Moira,' Burwood.
1894		Tooth, Arthur W., Kent Brewery.
1879	P 1	Trebeck, Prosper N., J.P., 2 O'Connell-street.
1879		Trebeck, P. C., F. R. Met. Soc., 2 O'Connell-street.
1877		‡Tucker, G. A., c/o Perpetual Trustee Co. Ld., 2 Spring-street.
1900		Turner, Basil W., A.R.S.M., F.C.S., 14 Castlereagh-street.
1883		Vause, Arthur John, M.B., C.M. *Edin.*, 'Bay View House, 'Tempe.
1884		Verde, Capitaine Felice, Ing. Cav., via Fazia 2, Spezia. Italy.
1896		Verdon, Arthur, Australian Club.
1890		Vicars, James, M.C.E., M. Inst. C.E., City Surveyor, Adelaide.
1892		Vickery, George B., 78 Pitt-street.

Elected		
1876		Voss, Houlton H., J.P., c/o Perpetual Trustee Company Ld., 2 Spring-street.
1898		Wade, Leslie A. B., C.E., Department of Public Works.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1899		‡Walker, Senator J. T., 'Rosemont,' Ocean-street, Woollahra.
1901		Walkom, A. J., A.M.I.E.E., Mem. Elec. Assoc. N.S.W., Electrical Branch, G.P.O. Sydney.
1900		Wallach, Bernhard, B.E. *Syd.*, Electrical Engineer, 'Oakwood,' Wardell Road, Dulwich Hill.
1891		Walsh, Henry Deane, B E . T.C., *Dub.*, M. Inst. C.E., Engineer-in-Chief, Harbour Trust, Sydney.
1901		Walton, R. H., F.C.S., 'Flinders,' Martin's Avenue, Bondi.
1895		Ward. James Wenman, 1 Union Lane off George-street.
1898		Wark, William, 9 Macquarie Place; p.r. Kurrajong Heights.
1877		Warren, William Edward, B.A., M.D , M.Ch., Queen's University *Irel.*, M.D. *Syd.*, 268 Elizabeth-street, Sydney.
1883	P 12	Warren, W. H., Wh. Sc., M. Inst. C.E., Professor of Engineering, University of Sydney.
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, Parliamentary Draftsman, Attorney General's Department, 5 Richmond Terrace, Domain.
1876		Watson, C. Russell. M.R.C.S. *Eng.*, 'Woodbine,' Erskineville Road, Newtown.
1897		Webb, Fredk. William, C.M.G., J.P., Clerk of the Legislative Assembly; p.r. 'Livadia,' Chandos-street, Ashfield.
1876		Webster, A. S., c/o Permanent Trustee Co. of N.S. Wales Ld., 17 O'Connell-street.
1892		Webster, James Philip, Assoc. M. Inst. C.E., L.S., *New Zealand*, Borough Engineer, Town Hall, Marrickville.
1867		Weigall, Albert Bythesea, B.A. *Oxon.*, M.A. *Syd.*, Head Master, Sydney Grammar School, College-street.
1881		‡Wesley, W. H.
1878		Westgarth, G. C., Bond-street; p.r. 52 Elizabeth Bay Road.
1879		‡Whitfeld, Lewis, M.A. *Syd.*, 'Oeta,' Queen-street, Woollahra.
1892		White, Harold Pogson, F.C.S., Assistant Assayer and Analyst, Department of Mines; p.r. 'Quantox,' Park Road, Auburn.
1877		‡White, Rev. W. Moore, A.M., LL.D., T.C.D.
1874		White, Rev. James S., M.A., LL.D. *Syd.*, 'Gowrie,' Singleton.
1883		Wilkinson, W. Camac, M.D. *Lond.*, M.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 207 Macquarie-street.
1876		Williams, Percy Edward, Government Savings Bank, Sydney.
1901		Willmot, Thomas, J.P., Toongabbie.
1878		Wilshire, James Thompson, F.L.S., F.R.H.S., J.P., 'Coolooli,' Bennet Road, Neutral Bay.
1879		Wilshire, F. R., P.M., Penrith.
1890		Wilson, James T., M.B., Mast. Surg. Univ. *Edin.*, Professor of Anatomy, University of Sydney.
1873		Wood, Harrie, J.P., 10 Bligh-street; p.r. 54 Darlinghurst Road.
1891		Wood, Percy Moore, L.R.C.P., *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road, Ashfield.
1899	P 2	Woolnough, W. G., B. Sc., F.G.S., University of Adelaide.
1876	P 1	Woolrych, F. B. W., 'Verner,' Grosvenor-street, Croydon.
1898		Wright, John, C.E., Toxteth-street, Glebe Point.

Elected		
1879		Young, John, 'Kentville,' Johnston-street, Leichhardt.

Honorary Members.

Limited to Thirty.

M.—Recipients of the Clarke Medal.

1901		Baker, Sir Benjamin, K.C.M.G., D. Sc., LL.D., F.R.S., etc., 2 Queen Square Place, London, S.W.
1875		Bernays, Lewis A., C.M.G., F.L.S., Brisbane.
1900		Crookes, Sir William, F.R.S., 7 Kensington Park Gardens, London W.
1875	M	Ellery, Robert L. J., F.R.S., F.R.A.S., c/o Government Astronomer of Victoria, Melbourne.
1887		Foster, Sir Michael, M.D., F.R.S., Professor of Physiology, University of Cambridge.
1875	M	Gregory, The Hon. Augustus Charles, C.M.G., M.L.C., F.R.G.S., Brisbane.
1875	P 1 M	Hector, Sir James, K.C.M.G., M.D., F.R.S., Director of the Colonial Museum and Geological Survey of New Zealand, Wellington, N.Z.
1880	M	Hooker, Sir Joseph Dalton, K.C.S.I., M.D., C.B., F.R.S., &c., c/o Director of the Royal Gardens, Kew.
1892		Huggins, Sir William, K.C.B., D.C.L., LL.D., F.R.S., &c., 90 Upper Tulse Hill, London, S.W.
1888	P 1 M	Hutton, Captain Frederick Wollaston, F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1901		Judd, J. W., C.B., F.R.S., F.G.S., Professor of Geology, Royal College of Science, London.
1901		Newcomb, Professor Simon, LL.D., Ph. D., For. Mem. R.S. Lond., United States Navy, Washington.
1894		Spencer, W. Baldwin, M.A., Professor of Biology, University of Melbourne.
1900		Thiselton-Dyer, Sir William Turner, K C.M.G., C.I.E., M.A., B.Sc., F.R.S., F.L.S., Director, Royal Gardens, Kew.
1895		Wallace, Alfred Russel, D.C.L. *Oxon.*, LL.D. *Dublin*, F.R.S., Parkstone, Dorset.

Obituary 1901.

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1888		Tate, Professor Ralph, F.G.S., F.L.S.

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1864		Adams, P. F.
1894		Carleton, H. R.
1878		Colquhoun, George
1880		Cox, Hon. G. H., M.L.C.
1868		Garran, Hon. Dr. Andrew
1879		Stephen, Hon. S. A.
1876		Tibbits, Dr. W. H.
1872		Wright, Dr. H. G. A.

AWARDS OF THE CLARKE MEDAL.

Established in memory of

THE LATE REVD. W. B. CLARKE, M.A., F.R.S., F.G.S., &c.,

Vice-President from 1866 *to* 1878.

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia.

1878 Professor Sir Richard Owen, K.C.B., F.R.S., Hampton Court.
1879 George Bentham, C.M.G., F.R.S., The Royal Gardens, Kew.
1880 Professor Huxley, F.R.S., The Royal School of Mines, London. 4 Marlborough Place, Abbey Road, N.W.
1881 Professor F. M'Coy, F.R.S., F.G.S., The University of Melbourne.
1882 Professor James Dwight Dana, LL.D., Yale College, New Haven, Conn., United States of America.
1883 Baron Ferdinand von Mueller, K.C.M.G., M.D., PH.D., F.R.S., F.L.S., Government Botanist, Melbourne.
1884 Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Canada, Ottawa.
1885 Sir Joseph Dalton Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., &c., late Director of the Royal Gardens, Kew.
1886 Professor L. G. De Koninck, M.D., University of Liège, Belgium.
1887 Sir James Hector, K.C.M.G., M.D., F.R.S., Director of the Geological Survey of New Zealand, Wellington, N.Z.
1888 Rev. Julian E. Tenison-Woods, F.G.S., F.L.S., Sydney.
1889 Robert Lewis John Ellery, F.R.S., F.R.A.S., Government Astronomer of Victoria, Melbourne.
1890 George Bennett, M.D. Univ. *Glas.*, F.R.C.S. *Eng.*, F.L.S., F.Z.S., William Street, Sydney.
1891 Captain Frederick Wollaston Hutton, F.R.S., F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1892 Sir William Turner Thiselton Dyer, K.C.M.G., C.I.E., M.A., B.SC., F.R.S., F.L.S., Director, Royal Gardens, Kew.
1893 Professor Ralph Tate, F.L.S., F.G.S., University, Adelaide, S.A.
1895 Robert Logan Jack, F.G.S., F.R.G.S., Government Geologist, Brisbane, Queensland.
1895 Robert Etheridge, Junr., Government Palæontologist, Curator of the Australian Museum, Sydney.
1896 Hon. Augustus Charles Gregory, C.M.G., M.L.C., F.R.G.S., Brisbane.
1900 Sir John Murray, Challenger Lodge, Wardie, Edinburgh.
1901 Edward John Eyre, Walreddon Manor, Tavistock, Devon, England.

AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

The Royal Society of New South Wales offers its Medal and Money Prize for the best communication (provided it be of sufficient merit) containing the results of original research or observation upon various subjects published annually.

Money Prize of £25.

1882 John Fraser, B.A., West Maitland, for paper on 'The Aborigines of New South Wales.'

1883 Andrew Ross, M.D., Molong. for paper on the 'Influence of the Australian climate and pastures upon the growth of wool.'

The Society's Bronze Medal and £25.

1884 W. E. Abbott, Wingen, for paper on 'Water supply in the Interior of New South Wales.'

1886 S. H. Cox, F.G.S., F.C.S., Sydney, for paper on 'The Tin deposits of New South Wales.

1887 Jonathan Seaver, F.G.S., Sydney, for paper on 'Origin and mode of occurrence of gold-bearing veins and of the associated Minerals.

1888 Rev. J. E. Tenison-Woods, F.G.S., F.L.S., Sydney, for paper on 'The Anatomy and Life-history of Mollusca peculiar to Australia.'

1889 Thomas Whitelegge, F.R.M.S., Sydney, for 'List of the Marine and Fresh-water Invertebrate Fauna of Port Jackson and Neighbourhood.

1889 Rev. John Mathew, M.A., Coburg, Victoria, for paper on 'The Australian Aborigines.

1891 Rev. J. Milne Curran, F.G.S., Sydney, for paper on 'The Microscopic Structure of Australian Rocks.'

1892 Alexander G. Hamilton, Public School, Mount Kembla, for paper on 'The effect which settlement in Australia has produced upon Indigenous Vegetation.'

1894 J. V. De Coque, Sydney, for paper on the 'Timbers of New South Wales.'

1894 R. H. Mathews, L.S., Parramatta, for paper on 'The Aboriginal Rock Carvings and Paintings in New South Wales.'

1895 C. J. Martin, B.Sc., M.B. *Lond.*, Sydney, for paper on 'The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*).'

1896 Rev. J. Milne Curran, Sydney, for paper on 'The occurrence of Precious Stones in New South Wales, with a description of the Deposits in which they are found.'

PRESIDENT'S ADDRESS.

By A. Liversidge, LL.D., F.R.S., Hon. F.R.S., *Edin.*
Professor of Chemistry in the University of Sydney.

[*Delivered to the Royal Society of N. S. Wales, May 1, 1901.*]

Before resigning the honourable position to which you elected me a year ago, it is according to our custom, my duty to address you upon the affairs of the Society and such other matters as may appear fitting upon the occasion of this our Seventy-ninth Anniversary.

The most important event which has happened since we last met is the death of our venerated and deeply beloved Sovereign, Her Most Gracious Majesty Queen Victoria; as the Society was in recess at the time, I, as your representative, forwarded through the kind offices of His Excellency the Governor-General, a telegraphic message of condolence to His Majesty the King and Royal Family; to this an appreciative reply has been received from His Majesty. In confirmation of that telegram I may, perhaps, be permitted to say, on behalf of the members of the Society, at this our first meeting since the sad event, that while mourning the loss of our great and good Queen we wish to respectfully offer to His Majesty, our loyal congratulations upon his accession to the Throne and our cordial wishes that his reign may be long, happy and prosperous, also that it may be characterized, like that of Her late Majesty, by marked progress in the advancement of science, literature and art, and in the amelioration of the condition of the people.

I had intended to address you almost exclusively upon chemical subjects, but after further consideration decided that it might, perhaps, be better to refer to other matters instead, matters which may be of more general interest to our members; some of them are connected with what may be termed the domestic affairs

of the Society, and some of the others are objects which I think the members of this Society can do much to promote; such as the introduction and improvement of science teaching in schools, the use of the metric system of weights and measures, the preparations for the International Catalogue of Scientific Literature, now being published in London, and commercial education.

Financial Position.—The Hon. Treasurer's Financial Statement shows that the financial affairs of the Society are in a fairly satisfactory condition.

The Library.—From the Balance Sheet submitted this evening it will be seen that a large proportion of our limited income continues to be spent upon the Society's Library, viz., £226 16s. 4d., of which £106 13s. 8d. was spent upon books and periodicals, £79 8s. 6d. for binding, and £70 14s. 2d. for additional shelving in the lower hall; the Council rightly regards the up-keep of the library as of the utmost importance; a good collection of current scientific literature is one of the greatest necessaries of a society of this kind; it is in fact absolutely essential for its work and well being; fortunately numerous Societies and Institutions, in all parts of the world, regularly forward their publications in exchange for our annual volume, but we still are much in need of funds to acquire the back numbers of many series, some of these are getting very scarce and the prices will soon become prohibitive, especially now that so many large libraries are being formed in America and elsewhere by wealthy benefactors. Perhaps someone in New South Wales will follow so good an example and earn the thanks of the present and of future generations.

Exchanges.—Last year we exchanged our journal with 421 kindred societies, receiving in return 224 volumes, 1669 parts, 85 reports, 263 pamphlets and 5 maps; a total of 2246 publications.

The following Institutions have been added to the Exchange List:—

Australasian Institute of Mining Engineers, Melbourne.
Botanic Gardens, Sydney.

British Economic Association, London.
British Medical Association, N.S.W. Branch, Sydney.
Department of Agriculture, Cheyenne, U.S.A.
Imperial Institute, London.
Mason University College, Birmingham.
Muséu Paulista, Sao Paulo, Brazil.
Western Society of Engineers, Chicago, U.S.A.

Papers read in 1900.—During the past year the Society held eight meetings, at which twenty-one papers were read; the average attendance of members was thirty-five, and of visitors three. The papers will duly appear in the Society's Journal, so that there is no necessity to repeat their titles here.

Four papers were read before the Engineering Section and they have been printed, together with the discussion upon them, in the Society's Journal; the Section held three meetings at which the average attendance of members and visitors was twenty-two.

Lectures—To add variety to the Society's meetings a course of five lectures has been delivered during the past year: they were so well attended by the members and their friends as to tax the capacity of our hall; as will be seen from the programme for 1901-1902 a course has also been arranged for the ensuing year, and it is to be hoped that similar courses of lectures will henceforth continue to be a feature of the Society's work.

Revision of Rules.—At the meeting held in December last, certain of the rules of the Society were revised, and the amendments have since been duly ratified this evening; the most important change is in the rules providing for the election of Honorary and Corresponding Members; the number of Honorary Members, who must be of eminent scientific attainments or distinguished promotors of the objects of the Society, has been increased from twenty to thirty (twenty of whom must be non-resident in Australia), and three can be elected in the year instead of two as heretofore. Corresponding Members will no

longer be elected, as it was found in practice, that the qualifications required of them were much the same as those possessed by Honorary Members.

Sections.—It is a matter of regret that nearly all the Sections have ceased to meet, the Engineering Section, however, is doing good work; it is to be hoped that some at least of the other Sections will be revived and that they will renew their career of usefulness, for there is no doubt that they afford useful opportunities for discussion and interchange of ideas which are not possible at the necessarily more formal meetings of the Society itself. I think that two or three of them could easily be resuscitated and made to do good work if energetic Secretaries for them were forthcoming.

I have, however, the pleasure to announce that steps have been taken to form a Section for Economic Science, mainly by the members of the late Economic Association, who recently joined this Society in a body; the new Section will have the sympathy and support of a large number of our members, and we all look forward to its apparently ensured success.

Roll of Members.—The number of members on the roll on the 30th April, 1900, was 374. During the past year sixteen new members were elected, the deaths numbered eight and the resignation fourteen, leaving a total of 368 on the 30th April, 1901.

The names of the members, which we have, to our regret, lost by death are:—

Belisario, Dr. John; elected 1875.
Knox, Sir Edward; elected 1875.
Neill, Dr. L. E. F.; elected 1890.
Shepard, A. D.; elected 1879.
Shewen, Dr. Alfred; elected 1882.
Steel, Dr. John; elected 1882.
White, Hon. R. H. D.; elected 1888.
Wildridge, John; elected 1898.

In 1890, when I was last privileged to address you from the chair the number of our members was 457, now it is only 368,

a drop of nearly one hundred, and it is the smallest number of members since 1885 when the roll stood at 494; from that date our members have, with an occasional slight recovery, slowly but steadily decreased. Complete lists of the members of the Society from its first formation are apparently not obtainable, but the following list, showing some of the fluctuations, is of interest. Perhaps some of our older members may have notes or papers from which the gaps between 1821 and 1867 can be filled in.

Philosophical Society of Australia, ...	1821,	10 members.
Australian Philosophical Society, ...	1855,	22 „
Philosophical Society of New South Wales,	1856,	153 „
„ „ „ „	1858,	174 „
„ „ „ „	1859,	186 „

Royal Society of New South Wales—

Year.	Members.	Year.	Members.
1867	108	1884	494
1868	118	1885	494
1869	118	1886	493
1870	127	1887	488
1871	129	1888	482
1872	134	1889	471
1873	118	1890	461
1874	155	1891	457
1875	264	1892	478
1876	297	1893	477
1877	346	1894	445
1878	408	1895	420
1879	404	1896	409
1880	457	1897	420
1881	452	1898	397
1882	475	1899	357
1883	486	1900	374

The decrease in the number of members is a matter of some concern and it deserves our serious consideration. It may perhaps, be accounted for in part by the Colony not yet having

recovered from the effects of the commercial depression which took place a few years ago; it is also doubtless due to the fact that there are now several societies in Sydney for special subjects, such as the Linnean Society of New South Wales, the Sydney Branch of the Royal Geographical Society of Australia, the Branch of the British Medical Association, the New South Wales Branch of the British Astronomical Association and others, all of which have tended to withdraw members or prevent new members from joining our Society; the Australasian Association for the Advancement of Science has also probably been a factor in bringing about the present reduction in our members, hence we need not necessarily attribute it to a loss of interest in Scientific matters on the part of the people of New South Wales.

Still another reason may be, that the residents of Sydney are now much scattered; since the opening of the suburban tram lines and the building of additional railways, miles of new suburbs have grown up, and many of the streets conveniently near to the Society's House, which a few years ago contained only private houses, in which many of our members resided, are now, more or less, occupied as professional offices and business premises; hence much larger numbers of the population live in the suburbs and as many such find a difficulty in attending our meetings they are deterred from joining the Society. On this account it may be desirable that we should consider whether it would not be better to hold our meetings in the afternoon, as is done by some of the more important societies in London on account of the very same difficulty; our members would then neither have to wait in town until eight o'clock nor make a second tedious journey into Sydney after perhaps a fatiguing day.

A further reason, and one which has probably had a great effect, is that the Society has of late years often omitted to give an annual conversazione; many besides our members are very much interested in the scientific apparatus, natural history specimens, inventions, etc., usually exhibited thereat; I think that the majority of our members much appreciate such evenings, and

largely because they can bring the ladies of their families; some of our members, as a matter of fact, only attend on such occasions; although such members do not all contribute directly to the scientific work of the Society they contribute to its resources, and they gain some knowledge of its work and objects; further the annual conversazione did much to interest visitors in the Society's work, hence I think it is unfortunate that these gatherings have had to be omitted so often of late years. Although rather a strain upon our funds, I am sure that in the end the Society greatly benefitted by the expenditure.

I do not think that we need fear a lack of novelties, "necessity is the mother of invention," and members will make efforts to maintain the character of these gatherings and even start their preparations many months in advance, if they know that there is to be a conversazione on a given date; the notice of a few weeks that we usually give intending exhibitors is insufficient, and many who are unable to prepare anything for exhibition at short notice might be able to do so if they had a longer one. Neither is it necessary to have a large number of exhibits, too many shown at one time tend to interfere with the intentions of the conversazione, as some objects of interest may be overlooked and others may be only imperfectly examined and appreciated.

I well remember that when the Society only met when papers had been contributed or promised for reading, it was quite a common thing for our monthly meetings to lapse for want of papers, but ever since we agreed to meet on the regular day, now some twenty-eight years ago, whether there were papers ready for reading or not, we have never failed to have material for the regular monthly meetings, hence I would strongly urge upon the members to do all they can to maintain the annual conversazione and an annual reception as well, in spite of ths difficulty of obtaining scientific novelties and the expense. We have had only two or three of the latter, but they have all been successful and have done good in promoting friendship amongst the members and a mutual knowledge of their scientific predilections and

attainments; results which would never be gained by the limited opportunities afforded by the more formal monthly meetings.

I feel confident that if we state on our annual programme, at the beginning of the session that there will be in addition to the regular monthly meetings, certain lectures, a reception, a conversazione as well as an annual dinner of the members, all on fixed dates, the Society will greatly benefit, and its objects will be largely promoted. Such gatherings are not merely social in their effects, for anything which brings the members together tends to the well being of the Society and to the advancement of science.

Honorary Members.—In December last, Sir W. Crookes and Sir W. T. Thiselton Dyer were elected Honorary Members.

Sir William Crookes, F.R.S., is a past President of the Chemical Society, of the Inst. of Electrical Engineers and of the British Association, and recipient of the Royal Medal and the Davy Medal awarded by the Royal Society of London. He is the editor of the "Chemical News," and of many works of reference upon technical chemistry, and is the author of numerous original researches, notably upon radiant-matter and similar subjects. Sir William was knighted in 1897 in acknowledgement of his eminent services to science. He has been elected an Honorary Member on account of his many brilliant and original researches and discoveries in chemistry, as well as on account of his great and long continued efforts for the promotion of science, and in recognition of the assistance he has given this Society by republishing our papers upon chemistry and allied subjects in the "Chemical News."

Sir William Turner Thiselton-Dyer, K.C.M.G., C.I.E., B.Sc., LL.B., Ph.D., F.R.S., Director of the Royal Gardens, Kew, and an Hon. Fell. of numerous English and Foreign Institutions and Societies. He is a Fellow of the University of London and a Hon. Fell. King's College, London, a late Fellow of University College, London, and author of many important botanical works, some of which relate to the flora of the Australasian Colonies. As the Director of the Kew Gardens he has done much, and

still continues to do everything within his power for Australian Botany. He has also assisted us in other ways; amongst the first collections received by the Sydney Technological Museum was a arge series of economic botany specimens presented by Sir William from the duplicates at the Kew Museum, unfortunately these were destroyed in the Garden Palace fire, but happily he was able to send out other specimens to replace most of those which were burnt. Sir William has gathered together at Kew Gardens, after many years labour, a library of Australian scientific journals and works, probably the most complete Public Library of the kind in existence. He has been elected an Honorary Member on account of his eminent services to the cause of science, and especially in recognition of the valuable results of his labours for the advancement of economic botanical science throughout the British Empire.

The Clarke Memorial Medal.—The Clarke Memorial Medal has been awarded for the year 1900 to Sir John Murray, K.C B., F.R.S., D.Sc., LL.D, Ph.D.

Sir John Murray is a Canadian by birth and was one of the Naturalists on board H.M.S. *Challenger* exploring expedition (1874-1877), he took a leading part in the investigation made by that expedition along the coast of New South Wales and other parts of Australia, and was also on other marine scientific expeditions. He was editor of the Reports of the Scientific Results of the *Challenger* Expedition, contained in fifty large quarto volumes, and is the author of numerous Reports and Monographs on Geography, Biology, etc. He was made a Knight Commander of the Bath in 1898, he is also a Knight of the Prussian Order of Merit and is the recipient of many English and Foreign medals awarded to him in acknowledgement of his services to science.

International Catalogue of Scientific Literature.—In an address to the Australasian Association for the Advancement of Science given in 1898, I drew attention to the work of the conference held in London by representatives of various countries, who had been appointed by their respective Governments for the purpose

of considering a proposal to publish an International Catalogue of Scientific Literature; since the above date, the arrangements for the preparation and publication of the catalogue have been practically completed, for almost all parts of the world except, I think, for some of the Australian Colonies, the blame for this certainly cannot be attached to the London Central Bureau, which has had charge of the matter, for I understand that they have been in constant communication with the various Australian Governments; that the Government of this State is well disposed towards the work is shown by its having subscribed for six copies of the Catalogue, which I understand are to be distributed to Government Institutions; (the Council has also ordered a full set of the Catalogue for our library), but up to the present, nothing seems to have been done to collect and forward material for the Catalogue from New South Wales and some of the other Australian States; the matter is of great importance and urgency as it is now May and the first set of volumes are to be issued during the year, hence this Society should at once undertake to do what it can in this direction.

It has been decided that the following branches of science shall be included within the scope of the Catalogue, each branch will be indicated by a letter of the alphabet, to be termed Registration Letters, as follows:

A. Mathematics.
B. Mechanics.
C. Physics.
D. Chemistry.
E. Astronomy.
F. Meteorology (including Terrestrial Magnetism.)
G. Mineralogy (including Petrology and Crystallography.)
H. Geology.
J. Geography (Mathematical and Physical.)
K. Palaeontology.
L. General Biology.
M. Botany.

N. Zoology.
O. Human Anatomy.
P. Physical Anthropology.
Q. Physiology (including Experimental Pathology, Pharmacology and Experimental Pathology.)
R. Bacteriology.

The subject-matters of the above sciences will be grouped under a convenient number of sub-headings, each of which will in turn be indicated by an appropriate symbol, usually a number. These symbols will be called Registration Numbers or Symbols as the case may be.

The Catalogue will be arranged according to subject-matter and to author's name. Literature published before January 1st, 1901, will not be included, neither will the Catalogue include what is termed Applied Science; technical matters of scientific interest will, however, be included and they will be referred to under their appropriate scientific headings.

The management of the Catalogue will be in the hands of (1) an International Convention, (2) an International Council, (3) Regional Bureaus, and (4) a Central Bureau in London.

(1.) The *International Convention* will have the supreme direction and control over the Catalogue; it will consist of delegates appointed by the respective Governments or other bodies which establish Regional Bureaus; (no region or district will be represented by more than three delegates), the convention will meet at regular certain stated times, viz., in 1905, 1910 and afterwards every ten years; during the intervals the affairs of the Catalogue will be administered by the International Council.

(2.) The *International Council.*—Each contracting Government or body can appoint one person to serve on the International Council, which will meet in London at least once in every three years, and at such other times as the Chairman and five other members may agree upon. The Council will have to submit a balance sheet and a report of its proceedings for publication in

some recognised periodical or periodicals in each of the contributing countries or constituent regions.

(3.) Organisations, termed *Regional Bureaus*, may be formed in any Country which declares its willingness to collect, provisionally classify and transmit to the Central Bureau, the matter relating to the Scientific Literature published in that country.

The catalogue will be edited and published by the *Central-Bureau* in London, of which Dr. H. Forster Morley has been appointed Director, acting under the direction of the International Council; so that the publication may be commenced during the present year, the Royal Society of London is advancing the necessary funds (about £4,000) until they are received from the contracting countries.

As the New Federal Government is hardly in a position to undertake the formation of a Regional Bureau it will be necessary for the Australian States either individually or collectively to take charge of their own literature. Unless this be done without delay, the scientific literature of some of the Australian States, including that of New South Wales, will be conspicuous by its absence from the catalogue. I need hardly say that any such omission would be a grave reflection upon us.[1]

The catalogue will probably contain between 160,000 and 200,000 entries each year and will fill seventeen vols. It is expected that the price will be about £17 per annum for the complete set; but separate vols., for special subjects will be issued, also copies printed on one side only will be obtainable for cutting up to form Card Catalogues, the original intention to issue the catalogue on cards as well as in volumes had to be abandoned on account of the expense and want of support. Each title will be catalogued at least twice, once in the authors' list and once in the list of subjects.

The subject indexes will in most cases give much fuller information than that afforded by the title of the paper, that is to say,

[1] Since the above was read this Society has undertaken the work for New South Wales.

the contents of the paper will also be indexed ; accordingly the authors and editors will be invited to assist in indexing their own publications ; their indexes will of course be edited by the Central Bureau in London, so as to render them uniform in character.

Authors in Australia will also, of course, be expected to prepare indexes for their publications, and they will doubtless do everything within their power to assist in carrying out this useful and much needed work.

This catalogue will be of immense value to original workers, of so great a value that it is quite impossible to express it adequately, as it will relieve them from a vast amount of labour in hunting up references in scientific journals, reports and monographs published in all parts of the world. As I have said on a previous occasion, it will be particularly valuable to us in Australasia, as we are so far removed from the great centres of scientific thought and activity as well as from the great public libraries and institutions for research.

A National Australian Academy.—I have long thought that a federation of the leading Scientific Societies in the Australian Colonies is desirable, and now that the colonies have been become federated as the Commonwealth of Australia, it would be more easy of accomplishment ; we have something of the kind in the Australasian Association for the Advancement of Science, but that is peripatetic and has only one short session of a week every two years, further the membership is largely of a very changeable character—it exists for a definite purpose, which differs from that of ordinary societies and it answers that purpose extremely well.

The organisation now suggested is of a different character and it would somewhat resemble, as far as the scope is concerned, the Continental Academies, but under rules more like those of the Royal Society of London. The members would be elected (from all of the States) on account of their scientific and other qualifications, the number of members would necessarily be limited and the seat of the Academy would, of course, be in the Federal Capital when built, where a suitable site for the

Academy's House should be reserved, as well as for Museums, Libraries, Art Galleries, and for other educational and scientific institutions, and for a Federal University; although the Academy might be organised upon somewhat similar lines to the Continental Academies, the members should certainly not receive a salary, as they do in some cases in Europe, but just as the English Government applies to the Royal Society of London for advice and assistance in certain matters, which is always given gratuitously, so the Federal Government might receive the benefit of the deliberations of the Australian Academy upon similar matters.

The chief difference between this proposed organisation and the existing Royal Societies in the various Australian States would be its federal character, and that its members would be elected only after having given proof, by original thought or work, of their fitness for membership.

A National Academy would, I think, be of great benefit to Australia, not only by its general usefulness, but the hope of election to it in the future would be a great stimulus to the younger scientific men; further, it would also bring together the best intellect of all the States for more systematic consideration and discussion of matters than is possible at the meetings of the Association for the Advancement of Science.

International Association of Academies.—In connection with this I may mention that an international Association of European Academies has recently been formed. A preliminary meeting was held in Wiesbaden in 1899, and another of the Council was held in Paris in July, 1900, at which the Royal Society of London was represented.

It was understood at the Wiesbaden meeting of the Association in 1899 that no Society devoted to one subject, or to a limited range of subjects, could be regarded as an "Academy" and admitted to the Association, unless its scope included both scientific and literary subjects; such a society might, however, be admitted to either the scientific or literary section of the Association.

Since the above was written an account of the International Association of Academies has appeared ("Nature," 28th March, 1901), taken from one by M. Gaston Darboux, permanent secretary of the Academy of Sciences, in the *Journal des Savants*.

From this it appears that the Royal Society and the Paris Academy took the initiative in the formation of this important association, the advantages of which were pointed out by Lord Lister, as President of the Royal Society, in a letter dated November 17th, 1898, to the President of the Paris Academy of Sciences.

Up to the present about twenty Societies and Academies have been admitted to the Association. Rules have been formulated regulating the admission of new Academies, the constitution of the council and committees, and for the government of the Association during the intervals between the meetings, which are to take place every three years.

At the Paris meeting three propositions were also considered. The Royal Society drew attention to the desirability of connecting Struve's measurements upon the arc of meridian, 30° east, with those of Gill on the same meridian in South Africa.

The Academy of Berlin brought forward the question of how best to facilitate access to manuscript and other documents. At the suggestion of the Paris Academy it was decided to regulate the standardisation of self-recording instruments used in physiology.

So much favourable interest has already been taken in the Association of Academies, that intended donations to it have already been announced. There is no doubt that its influence will be world wide. Whether an Australasian Academy, if formed, would be received into the International Association of Academies or not, it is desirable, in framing the constitution of an Australasian Academy, to bear the possibility in mind. There is no immediate need to form an Australasian Academy, but one ought to be founded eventually, and it is not amiss to give some consideration to the matter in good time. Federated

Australia should certainly do its utmost to take a fitting position in science as well as in other matters, and this can best be done by organising, for the men will be forthcoming if there are organisations to sympathise and help them with their work.

Science Teaching in Schools.—Amongst the subjects of interest to us is the question of science teaching in schools, and it would be very gratifying to many of us if with the new century and the inauguration of the Commonwealth of Australia, we should be privileged to see increased attention paid to this matter; it is sometimes suggested to individuals that with the new year they should turn over a new leaf, and it would be appropriate if the community turned over a new leaf with the new century, by insisting upon better provision being made for science teaching in schools.

At one time, from 1876 to 1887, a small amount of science was included in the University Matriculation Examination, and there is no doubt that its inclusion was beginning to have the good effect of causing some of the schools to introduce science teaching into their courses, but its subsequent removal in 1887 had the undoubted effect of checking the progress of science teaching in schools generally throughout the colony, and killing it completely in some. I do not quite understand the reasons for its removal, as I was away from the State at the time. I was informed that its removal was against the wishes of some of the schools, and I am sure that much good would result if it were again included. Our University is probably almost the only modern University which completely excludes science from its entrance examination.

Unfortunately the teaching of experimental branches of science, like chemistry and physics, involves an expenditure for apparatus, and this naturally acts as a deterrent, but I think that all who have any acquaintance with science teaching believe that the advantages warrant this additional expense. Science, even of the most elementary character, when properly taught, induces the pupil to observe and to think, as well as to exercise his memory;

to get a pupil to observe, and to think about what he sees and hears, is perhaps the most important and valuable point in any form of teaching; merely to know is not enough.

In order to train the powers of observation and thinking, efforts have been made of late years to so modify the methods of teaching physical science, and especially chemistry, so as to place the pupil in the position of a discoverer, *e.g.*, Professor Armstrong's Heuristic method. This method is very successful with small classes, or where there are plenty of demonstrators. I do not agree with those who think that Qualitative Analysis should not be taught in schools, but I think that instruction in it should be mainly confined to the principles involved; these should be taught very fully, and the experimental work should be so arranged as to illustrate those principles; practice in analysis can be taken up later on. Some of the teaching in science which is now done at the University ought to be done at school, and it is so done at many schools at Home and on the Continent; the student thereby gains valuable time at the University for things that he cannot do at school; the replacement of some elementary science in the matriculation examination would tend to bring this about; it is, perhaps, a platitude to remark that the University can exercise great influence upon the school teaching, whereas the schools can hardly affect the University curriculum; but it is sometimes beneficial to remind ourselves of well known things.

It would probably be better to have a leaving examination for schools instead of a matriculation examination at the University, and to include science in the former, but a leaving examination would be much more difficult to institute than reintroduce some science into the matriculation examination. It may be thought by some that these references to science teaching in schools would be better addressed to a different audience, but I think that members of this Society having a knowledge of, or taste for science, naturally wish their children to receive some instruction in it, hence, in addressing you, I feel that I am speaking to a sympathetic audience, the members of which can and

will use their influence for the promotion of science teaching in the schools of this State. I do not advocate the teaching of technical or applied science in ordinary schools; in fact it should not be taught at such schools; but the elementary principles of chemistry and physics should be taught, and taught thoroughly, both orally and by illustrative experiments, not because the latter are interesting and perhaps pretty, although if they are so much the better, but because the experiments either prove something or help to the understanding of something. The experimental demonstrations should in all cases be followed by practical exercises performed by the pupils themselves.

Technical education, or the practical application of science, should be reserved for the Technical Schools or Colleges, and to the University for the higher or professional branches. It may be thought that sufficient provision has already been made for technical and professional education in New South Wales, but I do not think that that is the case. It is quite true that New South Wales is not yet a large manufacturing country, but with its wealth of coal it ought to be one in a few years time, and we shall then want trained men to occupy highly responsible positions. Such men require the highest possible training, which must include a good broad foundation of general education upon which the professional education can be built; and it is none too soon for us to see that means for such training is provided, the weakest point at present being in the schools. The industries of a country cannot be maintained by capital and labour alone, the highly-trained intellect to direct and control is also required; *i.e.*, the co-operation of money, muscle, and brains is necessary.

The Metric System of Weights and Measures.—Closely connected with the subject of science teaching is the necessity for teaching the metric system of weights and measures. The so-called system of weights and measures used in Great Britain and its offshoots, came down to us from the early Egyptian times, but they have deteriorated in the process, for the measures of length, volume, and weight have not that systematic relationship to one

another which they originally possessed; the earliest records show that the unit of length (or a multiple or a fraction of it) cubed, formed the unit of volume, and the weight of water held by this cube formed the unit of weight.

The measures of length have been derived from the body, *e.g.*, the yard or stick in the time of Henry I. was said to be the length of his arm. Originally it seems to have been the ancient double cubit, but the yard has varied in length at different periods; the fathom is taken from the length of the outstretched arms; the foot speaks for itself; for smaller measures the width of the middle joint of the first finger was taken, and four of these digits made the palm or hand, still used in the measurements of horses. The width of the thumb was also taken as one of the smaller measures, equivalent to an inch. The pole or rod was a longer stick used for measuring greater lengths than the yard, and it varied from five to six yards in length; afterwards it was defined as five and a half yards, or sixteen and a half feet. The furlong was a furrow long, or the length ploughed by a yoke of oxen before turning. The mile, as is well known, was of Roman origin, and signified 1000 (mille) paces; its length varied considerably; in Scotland it was 1976 yards, in Ireland 2240 yards, and in Wales it was nearly four miles in length. On the Continent it was of even of greater lengths.

The term pound (*pondus*) simply means a weight, and this meant almost any weight between twelve and twenty eight ounces, the ounce being also of variable weight. The stone was originally simply a suitably big stone from a brook or river bed, used for weighing articles usually sold in large quantities; afterwards the stone itself was replaced by weights, but the term was retained; even then the weight varied, *e.g.*, the stone used for weighing glass weighed five pounds, that for meat weighed eight pounds, another weighed fourteen pounds, and that used for weighing cheese was sixteen pounds, while the stone for hemp weighed thirty-two pounds. Although some of these curious weights and measures have been got rid of, and there are many others

which I have not referred to, we still have two legal pounds, the (avoirdupois) lb. of 16 oz., or 7,000 grains, and the troy lb. of 12 oz. or 5,760 grains; also, two legal ounces, the troy ounce of 480 grains, and the avoirdupois ounce of 437·5 grains; there are also two drams of unequal weight. But the worst feature is that there is no simple connection between the measures of length, weight, and capacity.

James Watt is said to have been the first to propose that a universal system of decimal weights and measures should be employed throughout the world. He suggested the foot as the unit of length, and the cubic foot of water as the unit of weight, both divided decimally; the suggestion was discussed by English and French representative men of science, but rejected by us; the French adopted the decimal system in 1791, but with the metre as the unit, and it became law in 1799.

In the metric system the units of length, capacity, and weight are all directly related to each other. The unit of length, termed the metre, was intended to be a natural standard, and the one ten-millionth part of a polar quadrant of the earth, or arc of meridian, *i.e.*, of an arc drawn from the equator to the north pole, but subsequent measurements showed that the quadrant contains 10,001,472·5 metres, hence the metre is as much an arbitrary measure as the English yard. As the metre has turned out to be something different from what was intended, the length of the second's pendulum might after all have been taken as a standard, or even the English yard or the French ell. The metre is 39·37079 English inches, or rather more than three inches longer than our yard. For square or superficial measures the unit is the are, or 100 square metres. The other common measures are centiare, or square metre, and the hectare, or 10,000 square metres, equal to 2·47 acres. The unit for solid measure is the cubic metre or stère.

The cube of the tenth of a metre (decimetre) is the unit of volume or capacity, known as the litre, and it contains 0·22 gallon or 1.76 English pints, or 61·027 cubic inches. The unit of weight,

termed the gramme, is the weight of a cubic centimetre (the $\frac{1}{100}$ of a metre cubed) of distilled water weighed at its greatest density (4° C.), equal to 15·432 grains. The multiples of each of these are derived from the Greek, deka for ten, hecto for 100, kilo for 1000, and myria for 10,000. The prefixes for subdivision are taken from the Latin, the tenth of a metre, litre, or gramme, being the decimetre, deci-litre, and decigramme respectively; the hundredth parts are known as the centimetre, centilitre, and centigramme; the thousandth parts are the millimetre, the millilitre (more commonly called the cubic centimetre, and this in turn usually contracted into c.c.), and the milligramme. In every day life many of these terms are not used; lineal measurements, less than one metre in length, are usually given in millimetres only; it is not usual to state the length in both centimetres and millimetres, neither are the multiples, deca and hectometre, commonly used; such lengths are expressed simply as 10 and 100 metres, and so on for other lengths less than a kilo-metre, but the term kilometre is used because it is a convenient one, and it is employed in much the same way, for measuring distances, as we use the mile, of which it is roughly two-thirds. Myria-metre is also seldom employed. Small cubic measures are usually given in the terms of the cubic centimetre; for larger volumes the litre and hecto-litre and their multiples are the common commercial measures. So too with weights; practically only the terms milligrammes, grammes, and kilogrammes are used.

It is sometimes convenient to bear in mind the approximate values of some of the metric measurements as compared with English ones, especially for rough mental conversions, *e.g.*, the metre is about 10% more than the yard, the kilometre is about two-thirds of an English mile, 25 millimetres are about equal to one inch, or 100 millimetres to four inches. The kilogramme is equal to 2¼℔., or to 2℔. plus 10%; the limit of the international parcel post is fixed at five kilos (hence the English limit of 11℔s., which is practically 5 kilos); 1000 kilos equal 2200℔s., or 40℔s. less than a ton. The litre is equal to about 1¾ pints, or roughly

to 2 pints less 10%, and the hectolitre to about 22 gallons. Anyone with a knowledge of decimals will find no difficulty in using the system; a few minutes study enables anyone to understand it, and a very small amount of practice suffices for acquiring its use.

The metric system has now been in daily use in the University Chemical Laboratory for many years, and there has never been any difficulty in getting the students to use it intelligently at once. So great are its advantages, and so simple is the system, that it seems almost unnecessary to urge that its use be made compulsory. The principal reasons why it has not been made compulsory are not theoretical but practical ones, and the inertia naturally presented by large communities.

As previously stated this system was introduced into France in 1799 by the First Republican Government, and it has since been made compulsory in the following countries:—

Netherlands ...	1820	Brazil	1880
Columbia ...	1853	Argentine Republic	1887
Spain	1864	Egypt	1892
Germany ...	1872	Hungary... ...	1892
Switzerland ...	1873	Chili	
Sweden	1875	Mexico	
Austria	1887	Servia.	
Norway	1878		

It is also legal, but not compulsory, in Great Britain, the United States, Italy, Greece, Belgium, Hayti, Japan, Turkey, Portugal, New Granada, Roumania, etc., but it has not replaced the local systems in countries where its use is merely permissive.

Although employed officially in Egypt, Peru, and Venezuela, it has not come into use commercially.

It may be urged that it would be useless to employ a metric system of weights and measures with our present currency; that, however, is not the case, and if it were the case the difficulty could, I think, be easily overcome by making slight changes (*i.e.*

as far as the principle is concerned) in the value of some of the coins now in use, although the financial or commercial difficulties may be great. One very obvious way would be to use the half sovereign as a standard (this might appropriately be called a Victoria, after our late Queen, during whose reign it was introduced); the shilling is already the tenth of the half sovereign; the penny, which is also only a token, could be used as the tenth of a shilling, and the farthing, another token, could be used as the fifth of a penny, *i.e.*, until it was necessary to strike fresh coins; if necessary the farthing might be renamed the fifthing. The farthing is already of such small value that it would probably not be necessary to provide a still smaller coin, *i.e.*, the tenth of a penny (or $\frac{1}{100}$ of a shilling) corresponding to the continental centime, although it could be used in accounts. With the half sovereign as the unit a sum like £50 11s. 7½d. could be written V. 101 1 75, or V. 101·75.

If the sovereign were retained as the unit, and the florin as the tenth, and it was, I believe, introduced as the beginning of a decimal system of coinage, greater changes would be necessary, as the existing smaller silver coins do not conveniently fall into a decimal system which starts with the sovereign as the unit.

All multiplications and divisions would, of course, be exceedingly simple, as only decimals would be used. Of course there are objections to a decimal coinage, since 10 yields only two factors, viz., 2 and 5, which latter is rather a large one; decimal coins are for this reason inconvenient for small purchases, as they do not readily adapt themselves to such fractions as $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{3}$, but the disadvantages do not appear to outweigh the decided advantages possessed by a decimal system.

A duodecimal system, as the English is in part, lends itself to the existing duodecimal division of the hour, day, month and year. A consistent and complete duodecimal system of weights and measures, and of coinage, would be probably the most convenient of any, but the decimal system has been adopted by so many countries, that the introduction of the duodecimal system is

probably now out of the question. I had no intention of taking up the question of the decimal coinage, but having drifted into it I may, perhaps, let my remarks stand.

A recent report of the Decimal Association states that instruction in the principles of the metric system, and the advantages to be gained from it, has now been made compulsory in the upper standards of the English Elementary Schools; also, that negotiations are in progress for holding a conference in Paris of official delegates and others, from Great Britain, the United States, and Russia, to urge the adoption of the metric system of weights and measures in those countries. Active steps are also being taken in the United States, and a bill, now before Congress for the introduction of the metric system, has been favourably reported upon. The Government of Canada is said to be also seriously considering the advisability of adopting it. In Russia and Denmark there is an increasing disposition on the part of the Governments to render its use compulsory. Another report is from the Foreign Office; this was issued in July last, and contains the replies of Her late Majesty's representatives in Europe to a circular addressed to them by the Marquis of Salisbury, asking for information as to the actual experience of nations which had adopted the metric system.

The replies which came from over forty countries showed that the changes had, in all cases, been made without difficulty, and that there had never been any wish to return to the former system; also, that the adoption of the metric system had led to an increase of trade. The teaching of the metric system in schools is naturally made compulsory in all the countries using it. It is not because the English and American nations are less enlightened than some of the smaller countries of the world, and that they fail to appreciate the advantages of the metric system, but that they naturally count the cost before taking so serious a step.

The English system of measurements for marine engines, bolts, screws, pipes, etc., prevailed until recently all over the world, except in France, but as other countries are gradually adopting

metric measurements for such, it will be necessary for England to do the same, or much of our trade must gradually pass into the hands of others.

It must be borne in mind that to make the change to the metric system would involve a money loss of untold millions both to England and to the United States of America, since nearly all the present machinery would have to be altered; to take a single case only, instanced by a writer in a recent review, to adapt yard-wide looms to produce metric widths would mean an immense outlay of money, and a great loss of time; but unless this change be made a still greater loss will eventually ensue. In both countries it is used to a certain extent by some manufacturers and by instrument makers. I need hardly say that it is used by chemists and physicists in all parts of the British Empire. It is quite an easy thing for small, new, and non-manufacturing countries to adopt the metric system; it merely means a change in the method of buying and selling, and it does not involve the alteration or replacement, at a stupendous cost, of the manufacturer's plant and machinery.

I have brought the matter before the Society, although some of you are perfectly familiar with it, partly because it is one of scientific importance, and partly because I think that we should take an interest in the progress of the system, and also do what we can to make its use compulsory in Federated Australia, where I suppose its use is already permissive, as in Great Britain. A strong reason for its compulsory introduction is, that if all our arbitrary systems of weights and measures were replaced by it, children would probably save a year or two of their school time, which could be profitably spent upon other matters, *e.g.*, upon modern languages, elementary science and English composition, with the object of teaching them to think, and to put their thoughts into clear intelligible English. But the first step is to make it a compulsory subject of instruction in all schools attaining a certain standard; until that is done it is useless to think of making it the law of the land.

Commercial Education.—During the past few years we have been hearing a great deal about commercial education, and steps have been taken here by the Chamber of Commerce to promote and provide such education; but, although the matter is comparatively new to us, elaborate systems of commercial education have long been established, not only in various European countries but in Japan. The subject of professional commercial education is not only interesting to commercial men and certain educational institutions, but even to statesmen like Lord Salisbury, Mr. Chamberlain, and Lord Rosebery, who have all three drawn forcible attention to the urgent necessity there is for the training of the British merchant, so that he may maintain his position in the world. Unless something is done to enable him to meet his foreign competitors with equal educational and scientific weapons or equipment, it is thought by a few pessimists that it will soon be a question not whether he is to be one of Britain's proverbial merchant princes, but whether he is to exist at all. I think that this something can be effected, not necessarily by copying German, American, or Japanese methods, but by devising English methods for English needs, *i.e.*, we must work out our own salvation, as we have done in other cases, and can do again.

We were once taunted with being a nation of shopkeepers, but that was from envy of our wealth and resources; not that we deserve the taunt more than others, for the instinct for petty trading is probably, from what I have seen, more marked in many other countries than in our own. It has long been the aim of certain countries to acquire a knowledge of our commercial methods, and to emulate our successes, and for this purpose it is well known that numbers of foreigners take service in London offices at nominal pay, to the detriment of our own commercial men; the present systems of foreign commercial education had their origin in this same desire to compete with us, and now we are in danger of being surpassed in a department in which we formerly stood first.

It may be asked what have the members of this Society to do with commercial education? I think that our members have a

great deal to do with it; many of them are engaged in commerce, and their sons will in some cases also follow the same calling, and it is a matter of great importance to them that the education of the latter should be based upon scientific principles, and also include some instruction in science. Practically nothing which concerns mankind is a matter of indifference to us, and if it relates to organised knowledge of almost any kind, *i.e.*, "science," then it is a matter in which we are specially interested; as you are, of course, aware, one of the old titles of this Society was the Philosophical Society of Australasia; the name Philosophical Society was changed to Royal Society (by special permission of Her late Majesty) purposely to widen its scope, because it was considered that the term philosophy was not sufficiently comprehensive; under our present title we have no narrow boundaries. The higher forms of commercial education should be of professional rank, and this is the view now being held and advocated in England; accordingly, at the new University of Birmingham, it is proposed to have a Faculty of Commerce, with a professor, assistant professor, and instructor and special lecturers, in addition to those professors in other Faculties who will also take part in the teaching. The curriculum suggested, includes the usual subjects, such as mathematics, modern languages, various branches of science, geography, &c., and in addition instruction in business organisation, the theory and principles of trades unions, associations, trusts, commercial law, accountancy, shipping and railway practice, banking, exchange, etc. The commercial education is not to be a substitute for general education, but a supplement to it, and students are not to be allowed to enter upon it too early; it is thought that the age of twenty is quite early enough, and it is considered desirable that they should have taken a degree in Arts before proceeding to a degree in the Commercial Faculty, and that under any circumstances the highest commercial degree should only be given to those who have also an Arts degree. Night classes are not recommended, as it is felt that the proposed curriculum will employ all the energies of both students and teachers.

Although I have not seen it specifically stated that the course is to extend over four years, it is probably so intended, as all the other professional and scientific courses, *e.g.*, for mathematics, civil, electrical, and mining engineering, etc., are to be four year courses. It is rather expected that the fees will be sufficient to render the Faculty self-supporting, as they will probably amount to £50 a year. Our University also might, perhaps, take part in the higher professional commercial education of this country, without interfering with the work undertaken by the Chamber of Commerce. Co-operation would be of advantage to both, and more economical, for many of the teachers required are already provided at the University. In reference to this subject of commercial education, I should state that I am merely expressing my own opinions, and I have no knowledge of the views of other members of the University.

The following from " Nature," of March 28th, is interesting in reference to this subject:—" The Lord Mayor, in opening the proceedings in connection with the London School of Economics and Political Science, stated 'that the object of the school was to provide a scientific training in the structure and organisation of modern industry and commerce, and the general causes and criteria of prosperity as they were illustrated or explained in the policy and the experience of the British Empire and foreign countries. Mr. Passmore Edwards had generously contributed £10,000 towards the erection of a building for the Faculty of Economics and Political Science, and Lord Rothschild had given £5000.' In the course of his address Lord Rosebery said: 'From whatever standpoint we may regard the age, I think we must all be aware that we are coming to a time of stress and of competition for which it is necessary that we should be fully prepared. It is not necessary here to indicate what form that stress or that competition may take, but in military matters, in naval matters, in commercial matters, in educational matters, we see more clearly day by day that we shall not be allowed to rest on any reputation that we possess already, but that we shall have to fight for our

own hand in every department of human activity and human industry if we wish to keep our place. It is necessary for a nation in these days to train itself, by every available method, to meet the stress and the competition which is before it.' The United States Ambassador, in proposing a vote of thanks to the Lord Mayor, said, 'there was no doubt that colleges of economics and of political science were the latest development in the theory and practice of that education which was to fit men for the great affairs of life, as they were developing in the complex and rapidly varying phases of modern civilisation. In the United States they regarded them as among the chief means of maintaining the part in that rivalry which they were maintaining, and meant to maintain with all their force, with their sister nations of the world, and especially with this country, to which they were so much attached ; a rivalry, not of arms or of warfare, but a rivalry of brains, of skill, of courage in the great industries of life.' "

The above shows what the mother country has to contend with ; this rivalry will extend in due course to Australia, so let us prepare for it in good time.

CURRENT PAPERS, No. 5.

By H. C. Russell, B.A., C.M.G., F.R.S.

[With Diagrams.]

[*Read before the Royal Society of N. S. Wales, November 7, 1900.*]

This, the fifth list of current papers covers a period of thirteen months, *i.e.*, from October 1899 to November 1900 inclusive. The greatest number of papers received was 14 in February 1900. It is noteworthy that this is the first time I have had the greatest number of current papers in February. In 1899 the greatest number of papers was 14 in August; in 1898 the majority of papers 12, landed in October. In 1897, 10 papers landed in May; and of those in 1896, 11 landed in December. It thus appears that the majority of current papers has never been twice in the same month of the year so far. This fact may I think be taken to prove that there are changes in the ocean currents, and if this service is maintained, valuable data will be collected on the several tracks leading to Australia. On the mainland our meteorological work shews great changes in the winds from year to year.

In paper No. 2 (Vol. xxx., p. 206), I pointed out that an unusually strong prevailing N.W. wind over Australia had altered the distribution of current papers to some extent, and this time an interesting fact bearing upon this subject is found in the drift of No. 550, which was put into the sea off Cape Horn, and found its way on to the West Coast of Africa, in Ashantee. Assuming that the drift was a straight one it travelled 5,350 miles in a N.N.W. direction. Now all the current papers before, which have come to me, from Cape Horn have landed on Australia, and the few papers I have had from the Atlantic Ocean have drifted toward Mexico, except a few from the English Channel.

So far, it has not been possible to say definitely, the percentage of current papers received, compared with those thrown over to drift. But the practice has been very kindly carried out for me

by many captains of ships, whom I very cordially thank for their assistance, and I think, after this period, 7 years, it may be assumed that, considering the number of ships, about the same number of papers are set afloat each month, and in response for my request for a list of the papers set afloat (see list at end). Sixteen captains have sent me lists, from which it appears that during the period covered by this paper (thirteen months), no less than 448 papers have been set afloat. The papers received during the past thirteen months number 106, of these 20 have been more than thirteen months drifting, so that 86 papers thrown over during the interval come to me, that is, out of 448 set afloat 86, or 1 in 5 came back, which is much more than I anticipated. Referring to the effect of N.W. winds in a previous paper and their effect in preventing the landing of papers in the Australian Bight, it may be mentioned that the prevalence of southerly winds has been coincident with the landing of many current papers on the Australian Bight.

CURRENT PAPERS IN THE INDIAN OCEAN.

The following tabular statement, shews the distribution and rates of drift in the Indian Ocean, where the rate of drift is greater, and the same for the Atlantic :—

LANDING ON AUSTRALIA. LANDING ON AFRICA.

Number of Charts.	Interval includ in Chart.	Latitude S. 0° to 10°		Latitude S. 10° to 33°		Latitude S. 33° to 43°		Latitude S. 43° to 50°		Atlantic Ocean.	
		No. of Papers	Average drift in miles per day.	No. of Papers	Average drift in miles per day.	No. of Papers	Average drift in miles per day.	No. of Papers	Average drift in miles per day.	No. of Papers	Average drift in miles per day.
1893-4 No. 1	yrs. 3	0	0	0	0	1	7·0	5	7·8	0	0
1895-6 No. 2	2	0	0	2	16·1	6	8·6	3	9·1	0	0
1895-6 No. 3	2	4	10·9	3	13·7	4	6·1	3	10·1	0	0
1899 No. 4	1	0	0	3	15·2	5	9·4	2	12·3	4	6·1
1900 No. 5	1	1	15·6	3	21·4	5	6·7	3	7·5	0	0
No. of papers		5		11		21		16		4	
Average No. miles per day			13·3		16·6		7·6		9·4		6·1

from 1893 to 1900.

The tabular statement is most instructive, and it is to be regretted that we have so few papers; with more papers it would be possible to eliminate the effect of uncertainty in the date when the papers actually landed. In 1900, five papers were set afloat, one of these belong to section Lat. S. 0 to 10, another landed on a small island near Madagascar, shewing a rate of only 7·4, no doubt a case of delay in finding, and three others set afloat near the Cocos Island landed on Africa, shewing rates 18·3 miles, 20·6 miles, and 25·4 miles; extraordinary rates, and interesting in comparison with the paper that went from Cape Horn to Ashantee in the same year. 25·4 miles per day is, so far, the record drift with me; but all the drifts are rapid in latitude 10° to 33° south, in the Indian Ocean. "Referring to tabular list." Taking the average rates from Equator to 10° south the drift is 13·3 miles per day, mean of six papers; and the greatest 15·6 miles was in 1900, and the lowest rate 10·9 miles.

From 10° to 33° south 11 papers have been found in seven years, and the greatest daily drift is already mentioned, 25·4 miles per day, in 1900; and the average rate of the seven papers 16·6 miles per day. From latitude 33° to 43° south:—the average rate of drift per day in this section is 7·6 miles, and here the greatest rate of drift was in 1899 not 1900. Again in section 43° to 50° S., the greatest rate 12·3 miles per day was also in 1899. These facts are extremely suggestive and it is to be hoped that many more captains may take up the work. What we do know is very instructive. What we may know by increased effort will, I am sure, be most valuable both to commerce and science.

MONTHS IN WHICH THE CURRENT PAPERS WERE FOUND.

1899.			1900.										
Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Total
4	5	8	10	14	9	10	6	7	6	6	8	7	100

1896—December 11 current papers, greatest in one month.
1897—May 10 „ „

1898—October	12	current papers, greatest in one month.	
1899—August	14	"	"
1900—February	14	"	"

List of current papers extracted from the following list because they have been drifting for more than a year, the daily drift in several of these papers is so small that there can, I think, be no doubt they have been found long after they went ashore. It is an interesting and instructive list of twenty papers :—

Number of the Current Paper.	Number of Days travelling	Rate of progress per day in miles.	Miles travelled (direct).
494	743	2·5	1870
498	1403	0·6	830
499	1266	0·2	210
508	707	8·7	6150
510	528	7·3	3850
517	432	3·4	1475
518	383	1·4	540
520	690	0·5	329
524	487	4·0	1960
525	1447	1·6	2340
527	1195	4·5	5321
536	505	0·3	148
538	391	2.3	890
548	392	2·0	770
550	528	10·1	5350
554	406	1·2	470
557	422	3·7	1570
571	476	2·4	1037
580	687	9·2	6290
583	853	7·3	6250

DRIFT OF THE S.S. "WAIKATO."

The s.s. *Waikato*, just after passing the Cape of Good Hope, on June 5, 1899, broke her main shaft, and from that time to September 15, drifted about in the Indian Ocean. There will be found attached, a chart, shewing the various changes in direction which the ship made in the interval. I desire to express here, my very cordial thanks to Captain John M. Hart, for sending me a copy of his log during that anxious period. Other steamers may have to drift in the same waters, and the experience of the *Waikato* may be useful to them.

ABSTRACT OF LOG OF S.S. "WAIKATO."

1899. Date.	Noon. Lat. S ° ′	Noon. Lg. E. ° ′	Course.	Dist. miles per day	Bar.	Air.	Water.	Wind. A.M.	Wind. P.M.	State of Sea. A.M.	State of Sea. P.M.
June 5	37 30	21 00	2 a.m. tail	end	shaft	bro	ke.				
,, 6	36 48	20 51	N. 9¾ W.	42½	30·30	...	...	4 5 S.W.	4 4 Southerly		
,, 7	36 58	21 52	S. 84½ E.	51	·50	...	...	3 2 Westerly	2 1 Variable		
,, 8	37 44	21 40	S. 10½ W.	52	·46	62	68	Calm	Calm		
,, 9	37 12	20 12	N. 65½ W.	77	·34	63	67	,,	,,		
,, 10	37 28	19 20	S. 75 W.	42	·35	69	70	,,	,,		
,, 11	38 8	18 50	S. 28 W.	51	·45	68	69	,,	,,		
,, 12	39 3	18 27	S. 18 W.	58	·32	68	72	3 4 N.	4 4 N.		
,, 13	39 49	19 38	S. 50 E.	72	29·79	69	68	5 6 6 N.	7 8 N.W.		
,, 14	39 37	21 55	N. 84 E.	110	·58	55	59	7 5 4 S.W. W.	3 2 1 Variable		
,, 15	38 53	22 56	N. 28¼ E.	50	30·18	55	64	3 4 5 N.N.E.	7 6 5 N.N.E.		
,, 16	38 20	22 52	N. 31¾ E.	39	...	...	...	3 4 5 N.N.E.	7 6 5 N.		
,, 17	38 10	23 51	N. 77¼ E.	46¼	·00	64	62	4 4 N.	4 4 N.		
,, 18	38 16	25 3	S. 83¼ E.	53	29·93	62	65	4 5 S.W.	5 4 S.		
,, 19	37 26	25 13	N. 9 E.	51	30·	57	63	5 5 S.E.	4 5 E.S.E.		
,, 20	37 21	25 11	N. 18¼ W.	5	·23	64	67	5 5 E. N.E.	4 4 N.N.E.		
,, 21	37 37	25 23	N. 47¾ E.	24	·03	67	67	2 3 N.W. W.	4 5 Westerly		
,, 22	36 24	26 25	N. 30 E.	84	·09	64	62	4 4 Westerly	4 4 Westerly	Mod.	Mod.
,, 23	36 16	27 34	N. 81¾ E.	56	·26	58	64	4 3 2 S.W. S S.W.	2 1 S.	Slight	High
,, 24	36 43	27 50	S. 26 E.	30	·17	60	67	7 6 4 S.S.E.	8 7 6 S.	High	,,
,, 25	37 22	27 41	S. 10¼ W.	40	·65	55	65	4 4 S.	2 1 Variable	Mod.	Mod.
,, 26	37 46	27 28	S. 22¾ W.	26	·62	61	61	1 2 Variable	2 4 E.N.E.	Swell	,,
,, 27	37 46	26 50	West	30	·31	62	60	4 5 E.N.E.	2 2 N.E.	Mod.	,,
,, 28	37 54	26 30	S. 63¼ W.	18	·20	60	62	2 3 N. N.W.	4 5 6 W.N.W.	Slight	,,
,, 29	37 23	27 4	N. 41 E.	41	·22	62	60	5 6 W. S.W.	4 3 2 Southerly	Rough	Swell
,, 30	37 8	27 30	N. 45 E.	28	·39	60	58	Calm	2 3 4 N.W. W.	Swell	,,
July 1	37 18	27 56	S. 63¼ E.	22	·41	67	60	3 2 0 S.W. Calm	1 2 3 N.	,,	,,
,, 2	37 55	28 18	S. 22¼ E.	45	·33	66	64	2 3 N. N.W.	3 3 N.N.W.	Slight	Slight
,, 3	38 11	28 50	...	30	·20	65	66	3 3 N.	4 4 N.	,,	,,
,, 4	38 19	29 28	S. 76 E.	33	·03	67	66	4 4 Westerly	4 4 W. S.E.	,,	,,
,, 5	37 41	29 00	N. 30 W.	44	·15	62	65	5 4 E.N.E.	4 4 N.E.	,,	,,
,, 6	38 3	28 30	S. 47 W.	32	·14	68	67	4 4 N.N.E.	2 3 Variable	,,	,,
,, 7	39 11	28 40	S. 6¼ E.	68	29·96	64	66	3 4 N.	5 6 7 8 N.	,,	Rough
,, 8	39 53	30 20	S. 61 E.	87	·56	64	59	8 7 6 N.	6 7 8 W.S.W. W.	High	High
,, 9	40 1	31 14	S. 79¼ E.	44	·84	52	61	7 8 W. S.W.	8 7 8 W.S.W.	,,	,,

ABSTRACT OF LOG OF S.S. "WAIKATO."

1899. Date.	Noon. Lat. S. ° ′	Noon. Lg. E. ° ′	Course.	Dist. miles per day	Bar.	Air.	Water.	Wind. A.M.	Wind. P.M.	State of Sea. A.M.	State of Sea. P.M.
July 10	39 8	32 00	N. 33¾ E.	61	30·18	61	61	7 8 7 W.N.W.	6 5 4 W. W.S.W.	High	High
„ 11	38 45	32 39	N. 53½ E.	48	·50	60	59	3 1 Variable	2 3 4 Easterly	Mod.	Mod.
„ 12	38 35	32 20	N. 55½ W.	18	·36	59	59	2 2 N.E.	2 2 N.E.	Slight	Slight
„ 13	38 23	31 17	N. 76½ W.	52	·27	64	64	2 2 Westerly	4 5 N.E.	„	Mod.
„ 14	38 9	29 58	N. 78½ W.	67	·05	67	67	5 6 N.E.	6 5 N.N.E.	Rough	Rough
„ 15	38 37	29 00	S. 56½ W.	51	29·86	62	64	6 5 N.	7 8 7 W.N.W.	„	High
„ 16	37 43	29 36	N. 28 E.	61	30·13	61	64	6 5 4 W. N.W.	5 4 3 W.N.W	High	Rough
„ 17	37 15	30 03	N. 37 E.	35	·26	63	61	Calm	Calm	Mod.	Swell
„ 18	37 13	30 23	N. 84½ E.	20	·27	62	60	„	„	Smooth	„
„ 19	37 37	31 40	S. 68½ E.	66	·26	62	65	„	1 2 Westerly	„	„
„ 20	37 58	33 20	S. 76½ E.	88	·30	63	66	3 4 3 W.S.W.	Calm	„	„
„ 21	37 55	34 40	N. 87 E.	53	·36	65	65	Calm	1 2 3 N.E.	„	„
„ 22	38 4	35 20	S. 74½ E.	33	·32	63	64	3 4 N.N.E. N.	5 6 N.	Slight	Rough
„ 23	38 00	36 45	N. 86½ E.	68	·30	64	62	7 6 5 N.	4 4 N.	Rough	„
„ 24	38 22	37 40	S. 63 E	48	·37	61	60	4 5 N.	5 6 N.	„	„
„ 25	39 21	37 24	S. 12 W.	60	·13	60	59	5 4 N. N.N.W	6 7 8 N.W.	„	„
„ 26	39 32	37 52	S. 63½ E.	24	·31	57	61	7 7 6 W. S.W.	5 4 2 Southerly	High	Swell
„ 27	39 55	37 38	S. 25 W.	25	·65	62	63	2 1 2 S.W.	1 2 Variable	Swell	Slight
„ 28	40 10	37 37	S. 3 W.	15	·64	60	62	2 3 N.W.	3 4 N.W.	Tacora by took for a few	standing in tow hours.
„ 29	40 21	38 50	S. 79 E.	58	·26	60	62	...			
„ 30	39 30	38 56	N. 5 E.	51	·25	57	62	...			
„ 31	39 33	38 52	S. 40 W.	4	·17	64	61	...			
Aug. 1	39 38	39 4	S. 63½ E.	11	·16	64	64	2 3 W. W.S.W.	4 5 4 S.E. E.S.E.	Slight	Slight
„ 2	39 12	39 6	S. 3½ E.	26	·18	63	63	4 3 N.E. N.N.E.	4 5 4 N.N.E. N.	„	Mod.
„ 3	39 30	39 22	S. 34 E.	22	29·80	62	63	4 3 2 N.W. N.	3 4 N.W. W.N.W.	Mod.	Rough
„ 4	39 10	39 24	N. 1 E.	20	·79	60	62	4 5 S.W. S.	7 8 7 S.	High	High
„ 5	38 46	38 00	N. 69 W.	70	30·52	53	60	8 7 6 5 S. S.S.W.	5 4 S.W.	„	Swell
„ 6	38 45	37 52	N. 80 W.	6	·57	57	61	4 4 S.W.	Calm	Swell	Mod.
„ 7	39 17	37 32	S. 25 W.	36	·56	58	62	Calm	2 4 5 N.	Rough	High
„ 8	40 47	38 10	S. 17½ E.	94	·29	63	62	6 7 N.	7 8 N.	High	Rough
„ 9	41 31	38 40	S. 27 E.	49	·02	56	57	7 6 2 N.N.W.	1 1 Variable	„	Swell
„ 10	41 36	39 20	East	30	·10	52	52	1 1 Variable	Calm	Swell	Slight
„ 11	41 36	40 4	S. 81 E.	32	29·95	52	47	1 2 3 N.W. W.	2 3 N.W.	Slight	„
„ 12	41 45	40 20	S. 53 E.	15	·74	55	51	4 3 6 N.W.	5 4 3 N.	Mod.	Mod.
„ 13	41 58	41 2	S. 68 E.	35	·76	53	48	4 5 N.W. N.	6 5 6 N.W.	Swell	Swell

ABSTRACT OF LOG OF S.S. "WAIKATO."

1899. Date.	Noon. Lat. S ° ′	Noon. Lg. E. ° ′	Course.	Dist. miles per day	Bar.	Air.	Water.	Wind. A.M.	Wind. P.M.	State of Sea. A.M.	State of Sea. P.M.
Aug. 14	42 7	42 6	S. 79 E.	48	·89	48	49	6 5 4 5 N.W. W.S.W.	5 6 S.W.	Swell	Swell
,, 15	41 38	42 51	N. 49 E.	44	30·32	49	48	6 5 4 S.W. W.	4 5 6 N.W.	,,	,,
,, 16	42 32	43 3	S. 9 E.	55	·28	50	52	6 5 4 W.	4 5 N.W.	,,	,,
,, 17	43 2	43 52	S. 50 E.	47	·18	46	46	6 5 N.W.	4 3 2 W. S.W.	,,	,,
,, 18	43 7	44 14	S. 73 E.	17	·79	45	44	2 2 S.S.E E.	3 4 N.E.	,,	Mod.
,, 19	43 3	43 58	N. 69½ E.	11	·47	47	45	4 4 N.N.E. N.	5 6 N.	Slight	,,
,, 20	43 21	43 18	S. 60 W.	36	29·72	48	42	6 7 8 6 N. N.W.	4 3 2 W.	High	High
,, 21	43 35	44 00	S. 65½ E.	34	30·00	43	40	1 2 W.	2 4 5 N.N.W.	Swell	Mod.
,, 22	43 35	44 38	East	26	29·97	42	45	8 7 6 West	4 3 2 W.S.W.	Mod.	,,
,, 23	43 11	45 20	N. 52 E.	39	30·37	42	45	1 2 3 Vble. N N.E.	4 4 N.N E.	Swell	Swell
,, 24	43 38	45 20	South	27	·06	48	45	4 5 6 N.W.	6 5 5 N.W. W.	Mod.	Mod.
,, 25	43 56	45 17	S. 7 W.	18	·19	43	40	5 4 3 1 W. Variable	Calm	Rough	High
,, 26	43 56	45 25	East	5	·18	40	39	2 3 4 N.E. N.	4 5 6 N.	High	,,
,, 27	44 21	45 48	S. 33 E.	30	29·39	46	41	6 7 N.	7 7 N.W. W.	,,	Rough
,, 28	44 8	46 34	N. 68½ E.	36	·81	38	39	7 6 6 W. S W.	5 4 S.W.	,,	High
,, 29	43 33	47 20	N. 43 E.	48	30·17	39	39	3 2 1 Variable	2 4 6 7 N.N.E. N.	,,	,,
,, 30	44 5	48 2	S. 44½ E.	43	29·57	47	42	10 9 8 N.N.W.	8 7 7 4 N.W. W.	Rough	Rough
,, 31	44 8	48 35	S. 83 E.	25	30·05	40	40	4 5 6 7 W. N.W.	6 5 7 W.N.W.	High	High
Sept. 1	43 57	49 54	N. 79 E.	59	29·88	42	41	6 5 4 W.N.W. W.	4 5 7 W. N.W.	Rough	Rough
,, 2	43 27	50 58	N. 56¾ E.	55	·61 ·85	38	40	8 7 W.S.W.	7 7 W.S.W.	High	High
,, 3	42 15	51 50	N. 28 E.	81	30·17 ·51	40	43	7 6 S.W.	5 4 3 Southerly	,,	Rough
,, 4	42 2	52 34	N. 67¾ E.	34	·54	48	45	3 4 5 N.N.W.	5 6 N.N.W.	Mod.	,,
,, 5	42 14	53 45	S. 76½ E.	51	·33	50	48	6 7 N.W.	7 6 5 N.W.	High	High
,, 6	No o	bserv	ation.	...	·05	44	45	4 4 W.N.W.	4 3 4 W.N.W.	,,	,,
,, 7	41 54	55 34	N. 76 E.	83	·03	40	42	6 7 7 S.W.	6 5 4 S.S.W.	,,	,,
,, 8	41 1	56 40	N. 43 E.	72	·44	45	54	3 2 1 S.	2 3 4 N.N.W.	Swell	Slight
,, 9	41 4	57 25	S. 85 E.	34	·50	57	56	4 5 6 N.N.W. N.W.	5 5 N.W.	Mod.	Mod.
,, 10	41 4	59 00	East	72	·45	58	58	5 6 N.W.	6 6 N.W.	Rough	Rough
,, 11	40 34	61 00	N. 71 E.	93	·06	59	59	7 8 N.W.	7 6 5 S.W. W.S.W.	High	,,
,, 12	40 41	61 42	S. 78 E.	33	·15	56	57	4 3 E.S.E. E.	4 4 5 N. N.N.W.	Mod.	Mod.
,, 13	No o	bserv	ation.	...	29·83	58	60	6 7 8 N.W.	6 5 4 N.W.	Rough	Rough
,, 14	40 24	63 36	N. 79 E.	90	·94	53	54	3 4 5 S.W.	5 5 W.N.W.	Mod.	Mod.
,, 15	39 29	64 30	N. 37 E.	69	30·18	54	57	5 4 4 S W. S.	3 2 1 S.W.	,,	,,

LIST OF PAPERS SET AFLOAT BY THE SEVERAL SHIPS NAMED BELOW.

Date.	Name of Ship.	Number of Current Papers thrown overboard.
May 2 to Oct. 1, 1900 ...	M.M.S.S. "Pacifique" ...	37
Oct. 16 to Oct. 20, 1900	ditto ...	6
Jan. 11, to May 10, 1900	S.S. "Hauroto"	100
Sept. 7 to Sept. 27, 1900	ditto	29
Oct. 4 to Oct. 25, 1900...	ditto	23
Dec. 16/99 to Sep. 18, 1900	S.S. "Manapouri"	33
Oct. 4 to Oct. 24, 1900 ...	ditto	9
April 4 to April 25, 1900	R.M.S. "Victoria"	17
Sep. 8 to Sep. 22, 1900...	ditto	7
Nov. 22/99 to April 2, 1900	S.S. "Afric"	30
March 7 to April 1, 1900	S.S. "Gulf of Bothnia" ...	30
May 27 to June 21, 1900	ditto	30
Feb. 16 to March 7, 1900	R.M.S. "Himalaya" ...	18
Aug. 26 to Sep. 14, 1900	S.S. "Indraghiri"	17
Jan. 23 to Aug. 28, 1900	M.M.S.S. "Ville de la Ciotat"	50
Oct. 1 to Oct. 4, 1900 ...	S.S. "Yarrawonga"... ...	4
	Total ...	440

OCEAN CURRENTS.

Ref. No.	Date when put into the sea.	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated distance in miles	Rate per Day.	Ref. No.
492	Nov. 22-99	S.S. 'Afric'	— Alford, Commander ...	37 57 S.	137 31 E.	38 17 S.	142 0 E.	April 1-00	South Coast	130	240	1·9	492
493	May 23-00	"	" ...	37 0 "	137 16 "	37 43 "	140 15 "	Sept 4-00	"	104	700	6·7	493
494	Oct. 11-97	R.M.S. 'Alameda'	Van Otterendorp, Commd.	9 53 N.	163 5 W.	10 5 N.	169 10 "	Oct. 23-99	North Pacific	743	1,870	2·5	494
495	Nov. 9-99	" 'Aorangi'	W. C. Hay, Commander ...	21 30 S.	156 35 E.	31 5 S.	153 0 "	June 27-00	South Pacific	230	675	2·9	495
496	Dec. 6-99	M.M.S.S. 'Armand Behic'	A. Poydenot, " ...	34 3 "	114 29 "	33 42 "	114 55 "	Feb. 24-00	West Coast	80	38	0·5	496
497	Dec. 3-99	R.M.S. 'Austral'	A. J. Coad, " ...	35 31 "	128 23 "	32 15 "	126 17 "	April 7-00	South Coast	125	240	1·9	497
498	Aug. 9-96	"	J. F. Anderson, " ...	33 10 "	113 26 "	35 0 "	117 55 "	June 12-00	S. West Coast	1403	830	0·6	498
499	March 1-97	"	" ...	35 44 "	134 43 "	34 3 "	136 30 "	Aug. 18-00	South Coast	1266	210	0·2	499
500	Nov. 29-99	M.M.S.S. 'Australien' ...	— Verron, " ...	39 34 "	141 22 "	38 23 "	142 0 "	Jan. 9-00	"	41	95	2·3	500
501	Nov. 30-99	"	" ...	33 25 "	113 47 "	34 54 "	116 20 "	Dec. 26-99	S. West Coast	26	183	7·0	501
502	Jan. 2-00	"	" ...	35 8 "	118 36 "	34 55 "	118 53 "	Jan. 13-00	South Coast	11	60	5·5	502
503	Nov. 26-99	G.M.S. 'Bremen' ...	B. Nierich, " ...	35 31 "	137 10 "	35 16 "	138 31 "	Dec. 23-99	"	27	152	5·6	503
504	Oct. 31-99	R.M.S. 'Britannia' ...	F. H. Seymour " ...	38 40 "	142 22 "	38 26 "	141 40 "	Nov. 17-99	"	17	45	2·6	504
505	Feb 20-00	"	" " ...	38 28 "	141 30 "	38 24 "	142 30 "	March 4-00	"	12	58	4·8	505
506	Mar. 14-00	"	" " ...	36 54 "	139 11 "	36 50 "	139 53 "	Mar. 22-00	"	8	56	7·0	506
507	Oct. 27-99	"	" " ...	35 36 "	121 47 "	34 18 "	119 19 "	July 5-00	"	251	150	0·6	507
508	Dec. 17-97	S.S. 'Culgoa' ...	T. Blower, " ...	44 21 "	51 45 "	41 33 "	172 0 "	Nov. 24-99	South. Ocean	707	6,150	8·7	508
509	Sept. 8-99	R.M.S. 'Cuzco' ...	Lieut Pritchard, R.N.R., C.	35 36 "	132 45 "	33 20 "	134 48 "	Dec. 12-99	South Coast	95	190	2·0	509
510	Oct. 16-98	S.S. 'Darius' ...	W. Frith, Commander ...	20 57 "	101 23 "	12 30 "	45 0 "	Mar. 28-00	Indian Ocean	528	3,850	7·3	510
511	Jan. 5-00	H.M.S. 'Dart' ...	J. F. Parry, R.N., Commd ..	24 27 "	153 23 "	25 20 "	153 10 "	Feb. 8-00	East Coast ..	34	35	1·0	511
512	Jan. 8-00	"	" ...	32 18 "	152 54 "	32 12 "	152 25 "	Mar. 30-00	"	81	23	0·3	512
513	Oct. 4-99	Barque 'Dovenby' ...	Capt. Fegan, Master ...	44 51 "	164 49 "	39 20 "	173 44 "	Feb. 4-00	Tasman Sea	123	646	5·3	513
514	June 21-00	S.S. 'Elingamite' ...	W. Hipgrave, Commander	33 15 "	150 0 "	34 27 "	150 59 "	July 8-00	East Coast ..	17	220	12·9	514
515	Nov. 26-99	Brigantine 'Ethel' ...	F. Limschon, Master ...	38 18 "	147 42 "	37 46 "	149 17 "	Jan. 28-00	South Coast	63	100	1·6	515
516	March 8-00	"	" ...	39 9 "	143 25 "	37 56 "	147 55 "	May 8-00	"	61	120	2·0	516
517	Nov. 28-96	S.S. 'Fiona'	R. H. Smith, Commander	30 52 "	175 49 "	33 20 "	151 32 "	Feb. 3-98	South Pacific	432	1,475	3·4	517
518	Jan. 11-99	" 'Gulf of Ancud' ...	W. T. Currie, "	36 4 "	127 45 "	33 54 "	136 33 "	Jan. 29-00	South Coast	383	540	1·4	518
519	July 23-99	" 'Gulf of Bothnia' ...	T. G. W. Ligertwood, Com.	38 20 "	130 0 "	37 56 "	140 35 "	Dec. 20-99	"	128	555	4·3	519
520	Feb. 18-98	"	" "	35 52 "	130 14 "	32 57 "	134 14 "	Jan. 8-01	"	690	330	0·5	520
521	June 20-00	"	" "	35 45 "	131 20 "	37 47 "	140 19 "	Sept. 2-00	"	74	560	7·6	521
522	Jan. 21-00	"	" "	35 30 "	135 10 "	32 30 "	133 20 "	May 20-00	"	119	260	2·2	522
523	Mar. 14-00	"	" "	32 20 "	115 15 "	33 26 "	115 35 "	Sept. 2-00	West Coast ..	117	260	1·5	523
524	June 23-98	" 'Gulf of Venice' ...	T. Linklater, Commander	40 4 "	109 53 "	39 20 "	146 30 "	Oct. 28-99	South. Ocean	487	1,960	4·0	524
525	June 16-98	"	" "	40 0 "	97 40 "	38 3 "	140 43 "	June 2-00	"	1447	2,340	1·6	525
526	June 17-99	"	" "	39 55 "	102 58 "	33 50 "	123 36 "	May 4-00	"	321	1,165	3·6	526
527	Aug. 17-96	" 'Hawkes Bay' ...	M. O. C. Felgate, "	47 56 "	72 0	37 6 "	174 38 "	Nov. 24-99	"	1196	5,321	4·5	527

OCEAN CURRENTS.

Ref. No.	Date when put into the sea.	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated distance in miles.	Rate per Day	Ref. No.
528	March 2-00	R.M.S. 'Himalaya'	W. L. Broun, Commander	7 25 N.	77 30 E.	6 55 N.	79 50 E.	Mar. 29-00	Ceylon Coast	27	173	6·4	528
529	Nov. 5-99	"	" "	5 50 S.	89 45 "	1 20 S.	41 49 "	June 6-00	Indian Ocean	213	3,310	15·6	529
530	Oct. 22-99	R.M.S. 'India'	W. D. G. Worcester, R.N.R.	12 55 N.	43 59 "	12 4 N.	43 35 "	Oct. 24-99	Gulf of Aden	2	33	16·5	530
531	Dec. 29-99	"	" ...	16 33 "	40 56 "	19 5 "	37 20 "	Feb. 17-00	Red Sea ...	50	256	5·1	531
532	Feb. 11-00	"	" ...	12 30 "	44 1 "	14 10 "	42 5 "	Feb. 18-00	Gulf of Aden	7	150	21·4	532
533	April 17-99	"	" ...	32 46 S.	113 12 "	34 25 S.	123 5 "	Feb. 27-00	South Coast	316	675	2·1	533
534	Nov. 10-99	"	" ...	35 44 "	132 32 "	33 45 "	136 53 "	Jan. 31-00	"	82	300	3·7	534
535	Feb. 2-00	"	" ...	41 17 N.	9 30 "	41 28 N.	12 55 "	Mar. 27-00	Mediterranean	53	172	3·2	535
536	Nov. 13-98	"	" ...	38 49 S.	142 54 "	38 44 S.	145 50 "	April 1-00	Bass Straits	505	142	0·3	536
537	Mar. 25-00	"	" ...	38 51 "	145 3 "	38 20 "	144 40 "	April 1-00	South Coast	7	45	6·4	537
538	Mar. 16-99	"	" ...	35 31 "	125 41 "	38 15 "	141 0 "	April 11-00	"	391	890	2·3	538
539	April 2-00	"	" ...	32 24 "	112 32 "	33 19 "	115 38 "	June 21-00	West Coast	81	190	2·3	539
540	Mar. 31-00	"	" ...	35 12 "	124 8 "	36 0 "	139 30 "	Sept. 8-00	South Coast	161	835	5·2	540
541	Dec. 10-99	N.Y.K.S.S 'Kasuga Maru'	E. W. Haswell, Command.	26 0 "	153 24 "	28 59 "	153 35 "	Jan. 1-00	East Coast...	22	215	9·8	541
542	Dec. 12-99	" ...	" ...	30 52 "	153 13 "	31 8 "	153 5 "	Feb. 10-00	"	60	18	0·3	542
543	June 12-00	" ...	" ...	29 57 "	153 27 "	28 54 "	153 31 "	June 23-00	"	11	70	6·4	543
544	July 1-00	" ...	" ...	24 52 "	153 24 "	24 50 "	154 0 "	July 13-00	"	12	36	3·0	544
545	July 13-00	" ...	" ...	10 3 N	121 43 "	11 0 N.	121 55 "	Aug. 10-00	Sulu Sea ...	28	70	2·5	545
546	Sept. 16-99	S.S. 'Kini'	C. Suffern, Commander ...	38 44 S.	149 39 "	33 19 S.	151 34 "	April 16-00	East Coast ..	212	385	1·8	546
547	Feb. 3-00	" 'Langton Grange' ...	C. Crichton, " ...	38 0 "	134 53 "	35 39 "	139 0 "	June 1-00	South Coast	118	275	2·3	547
548	April 12-99	Barque 'Loongana' ...	W. T. Wawn, Master ...	26 26 "	156 5 "	19 6 "	146 51 "	May 9-00	East Coast ...	392	770	2·0	548
549	Jan. 15-00	S.S. 'Maori King'	— Hayward, Commander...	30 55 "	153 10 "	34 25 "	151 0 "	April 17-00	"	92	274	3·0	549
550	Sept. 23-98	Bq. 'Marechal de Turenne'	... ...	56 1 "	67 20 W.	5 20 N	3 30 W.	March 5-00	S. Atlantic ..	528	5,350	10·1	550
551	Nov. 30-99	R.M.S. 'Miowera'	F. A. Hemming, Command	11 43 N.	168 47 "	10 5 "	169 10 E.	Feb. 15-00	North Pacific	77	1,500	19·4	551
552	Jan. 28-00	S.S. 'Moravian'	A. Simpson, "	34 47 S.	118 57 E.	34 20 S.	119 0 "	Feb. 4-00	South Coast	7	30	4·3	552
553	Jan. 24-00	"	" "	38 18 "	140 48 "	38 15 "	141 38 "	Feb. 3-00	"	10	55	5·5	553
554	Dec. 4-98	R.M.S. 'Ophir'	H. E. Inskip, "	35 34 "	134 39 "	38 9 "	141 48 "	Jan. 14-00	"	406	470	1·2	554
555	June 3-99	" 'Orizaba'	A. McWatt, "	35 0 "	135 0 "	35 31 "	138 40 "	April 12-00	"	313	750	2·4	555
556	June 3-99	" "	" "	35 0 "	125 0 "	38 33 "	143 57 "	May 24-00	"	355	1,100	3·1	556
557	June 5-99	" "	" "	32 41 "	113 14 "	37 22 "	139 53 "	Aug. 1-00	South. Ocean	422	1,570	3·7	557
558	July 17-00	" 'Ormuz'	C. Nicholson, "	38 6 "	140 33 "	37 40 "	140 20 "	Aug. 13-00	South Coast	27	30	1·1	558
559	Aug. 24-00	" "	" "	7 21 N.	77 9 "	7 35 N	79 55 "	Sept. 6-00	Ceylon Coast	13	190	14·6	559
560	Oct. 13-99	Ship 'Samuel Plimsoll' ...	J. Henderson, Master ...	39 30 "	149 46 "	41 33 S.	148 20 "	Nov. 15-99	Bass Strait...	33	165	5·0	560
561	May 14-97	R.M.S. 'Rome'	A. B. Daniell, Commander	12 52 "	95 20 "	2 35 "	40 40 "	Oct. 10-97	Indian Ocean	149	3,785	25·4	561
562	Nov. 13-99	S.S. 'Salamis'	A. H. H. G. Douglas, Comd	34 19 "	24 13 "	34 4 "	22 58 "	Dec. 2-99	Cape Colony	19	60	3·2	562
563	Aug. 17-99	Ship 'Samuel Plimsoll' ...	J. Henderson, Master ...	2 50 N.	20 26 W.	5 20 N.	3 30 W.	March 5-99	N. Atlantic	200	1,175	5·9	563

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Ref. No.	Date when put into the sea	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated distance in miles.	Rate per Day.	Ref. No.
564	Dec. 14-99	S.S. 'Star of Victoria' ...	J. M. Hart, Commander ...	39 4 S.	142 50 E.	38 22 S.	142 20 E.	Dec. 25-99	South Coast	11	48	4·4	564
565	Dec. 12-99	,, ...	,, ,, ...	41 7 ,,	131 51 ,,	38 15 ,,	141 0 ,,	April 11-00	,,	120	550	4·6	565
566	Dec. 4-99	,, 'Talune'	— Spinks, ,, ...	45 55 ,,	163 51 ,,	46 52 ,,	167 42 ,,	Feb. 4-00	N. Zealand C.	62	140	2·2	566
567	June 25-99	,, ,, ...	,, ,, ...	39 55 ,,	170 24 ,,	41 10 ,,	172 15 ,,	Oct. 25-99	Tasman Sea	122	140	1·1	567
568	Oct. 19-99	M.M.S.S. 'Tanais' ...	A. Wünschmann, Commd.	31 22 ,,	154 52 ,,	29 9 ,,	153 26 ,,	Nov. 2-99	East Coast ...	14	128	9·1	568
569	Aug. 2-99	,, ...	,, ,,	23 22 ,,	165 22 ,,	25 0 ,,	153 15 ,,	Jan. 16-00	,,	167	750	4·5	569
570	Dec. 9-99	H.M.S 'Tauranga'	Leslie Stuart, R.N. ,,	33 50 ,,	151 19 ,,	34 4 ,,	151 12 ,,	Dec. 11-99	,,	2	18	9·0	570
571	Oct. 24-98	S.S. 'Thermopylae'	W. Phillip, Junr., ,,	45 54 ,,	127 4 ,,	39 8 ,,	146 25 ,,	Feb. 12-00	South Ocean	476	1,037	2·4	571
572	Dec. 1-99	Ship 'Trafalgar' ...	J. Gleave, Master ...	41 40 ,,	129 32 ,,	38 25 ,,	145 20 ,,	April 24-00	South Coast	144	870	6·0	572
573	April 12-99	R.M.S. 'Victoria' ...	E. Crewe, Commander ...	6 18 N.	79 55 ,,	6 35 N	79 56 ,,	April 20-99	Ceylon Coast	8	24	3·0	573
574	Feb 25-99	,, ...	,, ,, ...	14 58 S.	97 39 ,,	3 15 S.	40 0 ,,	Sept. 27-99	Indian Ocean	214	4,400	20·6	574
575	Aug. 21-00	,, ...	,, ,, ...	38 5 ,,	140 31 ,,	38 8 ,,	141 40 ,,	Sept. 2-00	South Coast	12	65	5·4	575
576	May 21-99	M.M. 'Ville de la Ciotat' ...	— Fiaschi, ,, ...	35 39 ,,	133 11 ,,	35 54 ,,	138 4 ,,	Jan. 14-00	,,	238	271	1·1	576
577	Jan. 27-00	,, ...	,, ,, ...	38 24 ,,	139 21 ,,	38 33 ,,	142 46 ,,	Mar. 29-00	,,	61	190	3·1	577
578	April 22-00	,, ...	,, ,, ...	36 1 ,,	133 14 ,,	37 35 ,,	140 20 ,,	July 4-00	,,	73	400	5·5	578
579	Mar. 18-00	S.S. 'Waihora' ...	R. L. Smith, ,, ...	32 57 ,,	151 53 ,,	32 56 ,,	151 50 ,,	Mar. 21-00	East Coast ...	3	3	1·0	579
580	Jan. 20-98	,, 'Warrigal' ...	A. W. Bond, ,, ...	41 16 ,,	56 16 ,,	36 37 ,,	174 12 ,,	Dec. 17-99	South. Ocean	687	6,290	9·2	580
581	Jan. 6-00	R.M.S. 'Warrimoo' ...	J. D S. Phillips, Command	22 58 ,,	155 56 ,,	34 25 ,,	150 56 ,,	Feb. 24-00	East Coast	49	800	16·3	581
582	Sept. 18-97	S S. 'Woolloomooloo' ...	W. Pentin, ,, ...	35 24 ,,	133 15 ,,	32 18 ,,	127 6 ,,	Jan. 8-98	South Coast	112	400	3·6	582
583	Oct. 9-97	,, ,, ...	,, ,, ...	29 24 ,,	34 14 ,,	38 15 ,,	141 0 ,,	Feb. 8-00	Indian Ocean	853	6,250	7·3	583
584	July 9-00	,, 'Zealandia' ...	W. Waller, ,, ...	34 35 ,,	173 6 ,,	35 45 ,,	174 36 ,,	Aug. 9-00	N. Zealand C	31	130	4·2	584
585	Oct. 15-99	... ...	... ...	30 24 ,,	153 9 ,,	35 53 ,,	150 6 ,,	May 18-00	East Coast ..	215	430	2·0	585

The following Papers have been received since the preceding was arranged.

Ref. No.	Date when put into the sea	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated distance in miles.	Rate per Day.	Ref. No.
586	Jan. 20-00	R.M.S. 'Arcadia' ...	A. C. Loggin, Commander	35 9 S.	126 1 E.	34 45 S.	135 55 E.	Oct. 7-00	South Coast	260	600	2·3	586
587	Jan. 6-00	,, 'Austral' ...	A. J. Coad, ,,	13 7 ,,	95 57 ,,	1 14 ,,	41 50 ,,	July 27-00	Indian Ocean	202	3,740	18·5	587
588	Aug. 29-00	,, 'Australia' ...	J. Reeves, ,,	37 27 ,,	139 17 ,,	37 12 ,,	139 45 ,,	Sept. 29-00	South Coast	31	30	1·0	588
589	Sept. 25-00	S.S. 'Gulf of Venice'	— Swan, ,,	35 42 ,,	136 38 ,,	34 57 ,,	138 38 ,,	Oct. 28-00	,,	33	115	3·5	589
590	Sept. 27-00	,, 'Hauroto' ...	W. J. Newton, ,,	35 36 ,,	175 26 ,,	36 5 ,,	175 23 ,,	Oct. 24-00	N. Zealand C.	27	30	1·1	590
591	Oct. 3-00	,, 'Kasuga Maru'	E. W. Haswell, ,,	15 25 ,,	145 22 ,,	15 15 ,,	145 25 ,,	Oct. 7-00	East Coast ...	4	15	3·8	591
592	Sept. 11-00	,, ...	,, ,,	29 44 ,,	153 32 ,,	34 10 ,,	151 20 ,,	Oct. 14-00	,,	33	340	10·3	592
593	Dec. 29-99	,, ...	,, ,,	29 21 ,,	153 39 ,,	28 55 ,,	153 30 ,,	Oct. 26-00	,,	301	30	0·1	593
594	April 13-00	R.M.S 'Victoria' ...	E. Crewe, ,,	35 49 ,,	132 13 ,,	36 0 ,,	139 5 ,,	Oct. 25-00	South Coast	195	380	2·0	594
595	June 1-00	,, 'Warrimoo' ...	J. D. S. Phillips, ,,	1 45 ,,	179 13 ,,	1 15 ,,	176 40 ,,	July 10-00	South Pacific	39	180	4·6	595
596	July 8-00	S.S. 'Zealandia' ...	W. Waller, ,,	34 12 ,,	168 30 ,,	33 30 ,,	172 42 ,,	Sept. 30-00	Tasman Sea	84	250	3·0	596
597	Dec. 7-99	R.M.S. 'Miowera' ...	F. A. Hemming ,,	11 3 ,,	167 51 ,,	8 15 ,,	159 30 ,,	Aug. 9-00	South Pacific	245	580	2·4	597

PRELIMINARY NOTES ON THE INTERMEDIARY HOST OF *FILARIA IMMITIS*, LEIDY.

By THOMAS L. BANCROFT, M.B. *Edin.*

[*Read before the Royal Society of N. S. Wales, June 5, 1901.*]

Filaria immitis is a large worm-parasite of the dog, common throughout the world, especially in the warmer parts; it is from five to ten inches in length, the males being much smaller than the females; it takes up its abode generally in the right ventricle of the heart and in the pulmonary artery. These worms are very prolific, producing large numbers of young, the so-called embryos; the latter swim about in the blood; a single minim of blood frequently containing twenty or more of them, the number depending of course on the number of fertile females in the dog; the embryo is about $\frac{1}{90}$ inch in length by $\frac{1}{3800}$ inch in breadth.

That distinguished scientist, the late Dr. Spencer Cobbold taught us that an intermediary host was necessary to transmit the parasite from dog to dog, and his opinion was accepted as correct.

Many workers in various countries, more particularly Grassi, Sonsino and J. Bancroft, endeavoured to discover the intermediary host; the dog-flea *Pulex serraticeps* was suspected, but no one could trace the young filariæ in its body after the blood containing them was digested. The different dog lice and ticks were likewise examined but with negative results. The writer has been endeavouring for the past thirteen years to find the intermediary host; at first numerous examinations of the *Pulex serraticeps* were made, afterwards of the common horse fly *Stomoxys sp.* ?; *Culex vigilax*, Skuse, a day-flying mosquito; the intestinal worm-parasite of the dog the *Anchylostoma* or *Dochmius trigonocephalus*. All these animals abstract together with blood the embryos, but

the latter appear not to enter upon a metamorphosis, and after several days can no longer be traced; it is thought that they are digested.

It occurred to me as possible, that a metamorphosis was not necessary, but merely that the embryo should go through a cold stage for a few days in the body of an insect, after which should it gain entrance into a dog it would start upon its final development. To test this hypothesis, a feeding experiment on a puppy was made. The dog swallowed at various times during a month one hundred and ten *Stomoxys* flies gorged with filariated blood; in each fly there were about fifty embryos. Every month afterwards the dog's blood was submitted to microscopic examination; at the expiration of eight months, two embryos were detected on a slide containing two minims of blood; a month later there were ten embryos in the same quantity of blood; the number however, after this date did not increase; the dog was killed and search made for the mature worms, three only were found in the heart, two females and a male. Now were the hypothesis correct we should expect to have found hundreds of mature worms. This dog must have been infected whilst with its mother; it was three or four months old when I got it, and whilst under observation it was kept apart from other dogs. The experiment not only disproved the hypothesis, but served another purpose, viz., the time taken by the young filaria to arrive at sexual maturity was ascertained to be not less than seven months and not more than a year.

In the British Medical Journal Nov. 3, 1900, p. 1306, there is a paper by B. Grassi and G. Noè of Rome, entitled "The propagation of the filariæ of the blood exclusively by means of the puncture of peculiar mosquitos." In this paper, mention is made that Grassi, whilst engaged experimenting with the malarial mosquito, the *Anopheles maculipennis*, Meigen, Syn. *A. claviger*, Fab., had observed filariæ in them, which he traced to be developmental forms of *Filaria immitis*. To Grassi therefore is due the credit of having discovered the intermediary host.

The authors of this paper remark:—"The embryos of *Filaria immitis*, sucked up with the blood by *Anopheles*, migrate into the malpighian tubes, where they continue their development, behaving more or less like the other blood filariæ already known. The larvæ, arrived at the maximum development possible in the body of *Anopheles*, abandon the malpighian tubes to enter the general cavity of the body, leaving behind the old cuticle, then they progress towards the head, and collect themselves there rapidly (as our transverse sections show very clearly) in the prolongation of the general cavity of the body within the labium, called also inferior labium, (exceptionally also in the palpæ).

"By proper experiments we have demonstrated that when *Anopheles* bites these larvæ come out of the labium, and are thus inoculated in the bitten animal. The mechanism of exit represents one of the most singular and admirable phenomena that one can imagine for the diffusion of parasites. . . . . . When the mosquito proceeds to penetrate the skin the labium buckles up at first towards the base, forming an obtuse angle. As the stylets gradually penetrate, the angle is advanced towards the middle of the labium, becoming extremely acute, so much so that when complete penetration is effected the labium appears doubled upon itself, forming a narrow kind of loop, and thus forms, through the conformation of the parts which close together, a new canal. . . It is certainly through the bending of the labium stuffed with filariæ that is brought about the rupture of the integuments of the labium; along the dorsal groove and through the rupture thus produced come out the filariæ to penetrate the body of their definitive host."

As the European mosquito, the *Anopheles maculipennis*, does not exist here, it is manifest some other insect must play the rôle of host in Australia. Early this year I was able to ascertain that the "House Mosquito," *Culex Skusii*, Giles, was the intermediary host. The embryos go into the malpighian tubes of the mosquito, as stated by Grassi, where they undergo a metamorphosis very similar to that of *Filaria nocturna*. In twelve days they have

grown to a remarkable size and can be easily seen in the malpighian tubes and are capable of slight movements. In eighteen to twenty days they have arrived at maturity as far as their life in the mosquito is concerned; they have left the malpighian tubes and lie in the alimentary canal about the head also in the labium; they are $\frac{1}{20}$ inch in length by $\frac{1}{500}$ inch in breadth.

If the proboscis of a filariated mosquito be cut off and mounted on a glass slide in water with cover-glass, and examined under the microscope, a slight pressure on the cover-glass being applied to cause the stylets to leave the labium, the young filariæ may be seen swimming up and down the apparent canal in the labium [what Grassi designates "the prolongation of the general cavity of the body within the labium]; a little further pressure on the cover-glass causes the worms to escape at the extreme end of the labium. Whether there be a natural opening at the labellar end of the labium seems doubtful, but in every instance in which the experiment was made the young filariæ escaped at this point, and at no other.

In several works on entomology, giving descriptions of the mouth organs of dipterous insects, [that are in my possession] there is no mention of a canal in the labium or of any opening at the tip. It seems to me that should no natural opening exist at the spot indicated, the young filaria would have very little difficulty in making one, and I believe that they naturally do leave their intermediary hosts at this point; here they could wriggle into the wound made by the mosquito and would avoid any risk of being sucked up with the blood.

The young filariæ placed in water wriggle about but are quite unable to leave the spot where they happen to lie; it is not unreasonable to conclude that, as they are so helpless in water, they could scarcely swim against the blood stream entering the mosquito. There is still another objection to Grassi's idea of a rupture; this occurs when the labium is "stuffed with filariæ," but it would not be likely to happen when the labium contains a single worm as is frequently the case.

We are now able to give an exact account of the life-history respectively of *Filaria nocturna* and *F. immitis*. Starting with the sexually mature worms in man and dog, these produce embryos, which swim in the blood; the mosquito in biting abstracts some of the embryos; these develop in the mosquito's body and in about three weeks time are capable of entering their final hosts should they get a chance of so doing. Sooner or later the mosquito may bite their final or definitive host, the filariæ seize the opportunity and pass into the puncture made by the mosquito in the skin; they now grow to sexual maturity, which probably takes about a year.

During the metamorphosis in the mosquito's body the position taken up by the filariæ serves to distinguish which is *Filaria nocturna* and which *F. immitis*, the former being in the thoracic muscles the latter in the malpighian tubes; whilst at their maximum development the chief characteristic mark is their size, the young *F. immitis* being shorter and thicker than the *F. nocturna*.

We have learnt that mosquitos live long periods, not a few days as was formerly thought but months, and that during their life time they bite frequently.

It is a remarkable fact that in Europe the *Anopheles maculipennis* plays the rôle of host for the malarial parasite, for *Filaria immitis*, and it is believed also for *Filaria nocturna;* whilst in Australia the "House Mosquito" *Culex Skusii*, Giles, [formerly thought to be a form of *Culex ciliaris*, Linn.][1] is host for *Filaria nocturna* and *F. immitis*, probably also for the malarial parasite.

I have recently found that dates, the dried fruit to be obtained from the grocer, are a most excellent food for mosquitos, very much better than banana [which some years ago I had discovered to be a valuable food for mosquitos in confinement]. Dates, as food for mosquitos, have these advantages over banana, they may

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[1] The "House Mosquito" of Australia appears to the writer to agree with the description given in Giles' work on Mosquitos, p. 298 of *Culex fatigans*, Wied.

be kept in a jar in the laboratory and are conveniently to hand at any time; a pound weight of them will serve for numerous experiments; they do not go rotten or even mouldy; and there is no necessity, as with banana, to change for fresh every three or four days; a single date hung in the mosquito cage will serve throughout the experiment however long it might last. Mosquitos fed on dates live longer, and many species that will not live in confinement more than three days on banana, *e.g. Anopheles musivus*, Skuse, *Culex vittiger*, Skuse, thrive on dates and live for upwards of a month.

In studying the life-histories of mosquitos it is often necessary to induce them to oviposit in confinement. I have found that when the water vessel in the cage contains putrid water mosquitos will often oviposit, whereas they refuse to do so on clean water. It is prudent however, to remove the eggs to cleaner water as the larvæ of many species cannot exist in putrid water. The water may be rendered suitably putrid by the addition of a little fresh cow-dung.

In a number of experiments made with the object of ascertaining whether certain very rare mosquitos [that would not live in confinement in glass jars of the capacity of a gallon of water] would live in larger cages and under more natural conditions; I made a cage having a capacity of about a cubic yard in which were placed several living plants in pots and large vessels of water both fresh and salt, but the mosquitos lived no longer in it. It seems therefore that nothing is gained by the use of such large cages.

TWO HISTORICAL NOTES IN REGARD TO CAPTAIN COOK THE CIRCUMNAVIGATOR.

By J. H. MAIDEN, Government Botanist and Director of the Botanic Gardens, Sydney.

[*Read before the Royal Society of N. S. Wales, June 5, 1901.*]

1. *The Club which, it is believed, partly contributed to his death.*—When recently in England, Mrs. Lowther of Shrigley Hall, Macclesfield, Cheshire, was kind enough to permit me to examine the collection of objects brought together by her father Thomas Legh Esquire of Lyme Hall, the Leghs being of course one of the most ancient families in the county. (Mr. Legh was known by his contemporaries as "Traveller Legh," and was one of the original Fellows of the Royal Geographical Society). The objects are mostly Egyptian and Oriental, but a South Sea Island Club at once attracted my attention. On my displaying interest in the club, Admiral Lowther (Mrs. Lowther's brother-in-law) was kind enough to say that he would have it and its label photographed and give copies to me. These I exhibit to you to night, after which I shall send them to the Australian Museum, where they will be always available for reference.

The label, old and faded, and evidently written early in the last century, is as follows :—

"Cap^{n}. Ja^{s}. Cook, the celebrated circumnavigator, born 27 October 1728, at Marton in Cleveland, near great Ayton in the County of York.

"Cap^{n}. Cook was killed on the 14 Feb^{y} 1779 by the Indians of Owhyee—he was first stabbed, and with a (the word *a* is crossed out and the word *this* inserted) Club gave him a blow on the back of the head.

"This is the identical Club, given to me by the late Admiral John Hunter."

Sir Jos^{h}. Banks, Bar^{t}. F.L.S. and K.B., Portland Place.
Dr. Solander
Cap^{n}. W^{m}. Bligh, R.N."

The original label was written by Mr. Legh, and was, Mrs. Lowther tells me, a copy of an extract of a letter by Sir Joseph Banks to Mr. Legh in presenting the club. How Admiral John Hunter (Governor of New South Wales, of course) obtained the club is not known to me, but ever since it was presented to Mr. Legh it has only been at Lyme Hall and Shrigley Hall, places five miles apart.

What the object of Mr. Legh was in adding the names of Solander and Bligh, I do not know. Probably they are mere memoranda.

Mr. F. M. Bladen, to whom I submitted the facsimile of the label, says that it is not in the handwriting of Sir Joseph Banks, Admiral Hunter nor Captain Bligh, and agrees that it is probably a copy made by or for Mr. Legh. He points out, however, that the document could not have been written as a whole at any given date. The paragraph commencing "this is the identical club" refers to the *late* Admiral John Hunter, and could not have been written by Banks, for Hunter survived him (Banks died in 1820, Hunter in 1821).

Perhaps however, the club was given by Admiral Hunter to Mr. Legh and the descriptive letter furnished by Sir Joseph Banks.

I give an extract from Kippis' abbreviated work (edition of 1883), and Mr. F. M. Bladen has been good enough to give me the original passage, giving the account of the death of Cook by Surgeon Samwell, an eye witness.

The club is of Ironwood *(Casuarina equisetifolia)*, a timber commonly used in the Islands for making such articles. It is about three feet long, the diameter at the thicker end is 2 inches and 1½ inches at the other end. The photograph is a clear one (two

photographs are of course necessary to show the whole of it), and if the pattern upon the club shows it to be of special interest, no doubt we shall be favoured with some observations by the Curator of the Australian Museum, an expert in regard to such objects.[1]

APPENDIX.

A. Kippis—Narrative of the Voyages round the World performed by Captain James Cook (1788) Edited and published by Bickers & Son, 1888, p. 341.

"Captn. Cook was making for the pinnace with his hand at the back of his head to protect himself from the stones hurled. A native with a large club or common stake gave him a blow at the back of the head."

Account of the manner of Capt. Cook's death, by David Samwell, Surgeon of the Ship Discovery. Printed in Kippis's Life of Cook.

. . . "At that time, it was to the boats alone that Captain Cook had to look for his safety; for when the marines had fired, the Indians rushed among them and forced them into the water, where four of them were killed; their lieutenant was wounded, but fortunately escaped, and was taken up by the pinnace. Captain Cook was then the only one remaining on the rock; he was observed making for the pinnace, holding his left hand against the back of his head, to guard it from the stones; and carrying his musket under the other arm. An Indian was seen following him, but with caution and timidity; for he stopped once or twice, as if undetermined to proceed. At last he advanced upon him unawares, and with a large club or common stake[2] gave him a blow on the back of the head

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[1] Since the above was written, Mr. R. Etheridge, the Curator, has been kind enough to favour me with the note below; I am further indebted to to him for the critical note in regard to the inscription (*infra*).

"The evidence as far back as Admiral Hunter is no doubt satisfactory, but anterior to that is very weak; Hunter may have obtained it in a dozen different ways. I can find no trace of a Hawaiian club so ornamented, but both the form and sculpture is decidedly Fijian, Samoan or Tongan, the last for choice. Cook, as you know was at Amsterdam Island (Tonga), and it is on record that great intercourse went on between the Tongans and Fijians. What is more probable than that the club formed part of the Cook-Banksian Collection, taken home by the '*Adventure*.' It is on record that Mrs. Cook's house at Clapham was a veritable museum, and there can be no question that specimens were given away freely before her death."

[2] NOTE—I have heard one of the gentlemen who were present say, that the first injury he received was from a dagger, as it is represented in the Voyage; but from the account of many others who were also eye witnesses, I am confident in saying, that he was first struck with a club, I was afterwards confirmed in this, by Kairee Rea, the priest, who particularly mentioned the name of the man who gave him the blow, as well as that of the chief who afterwards struck him with the dagger. This is a point not worth disputing about; I mention it, as being solicitous to be accurate in this account, even in circumstances, of themselves, not very material.

and then precipitately retreated. The stroke seem to have stunned Captain Cook; he staggered a few paces, then fell on his hand and one knee and dropped his musket. As he was rising, and before he could recover his feet, another Indian stabbed him in the back of the neck with an iron dagger. He then fell into a bight of water about knee deep, where others crowded upon him, and endeavoured to keep him under; but struggling very strongly with them, he got his head up, and casting his look toward the pinnace, seemed to solicit assistance. Though the boat was not above five or six yards distant from him, yet from the crowded and confused state of the crew, it seems it was not in their power to save him. The Indians got him under again, but in deeper water, he was however, able to get his head up once more, and being almost spent in the struggle, he naturally turned to the rock, and was endeavouring to support himself by it, when a savage gave him a blow with a club, and he was seen alive no more. They hauled him up lifeless on the rocks, where they seemed to take a savage pleasure in using every barbarity to his dead body, snatching the daggers out of each others hands, to have the horrid satisfaction of piercing the fallen victim of their barbarous rage."

2. *Inscriptions on a Mural Tablet and Gravestone commemorating some of Captain Cook's family.*

The Church of St. Andrew the Great, Cambridge, is to some extent identified with the family by the great circumnavigator. North of the altar is a handsome mural tablet with the following inscription:—

"In memory of Captain James Cook of the Royal Navy, one of the most celebrated navigators that this or former ages can boast of, who was killed by the natives of Owhyhee in the Pacific Ocean, on the 14th day of February, 1779, in the 51st year of his age.

"Of Mr. Nathaniel Cook who was lost with the *Thunderer* Man-of-War, Captain Boyle Walsingham, in a most dreadful hurricane, in October 1780, aged 16 years.

"Of Mr. Hugh Cook of Christ's College, Cambridge, who died on the 21st December, 1793, aged 17 years.

"Of James Cook Esquire, Commander in the Royal Navy, who lost his life on the 25th of January, 1794,[1] in going from Pool to

[1] The "Colonial and Indian" copy says 1794.—R.E.

the *Spitfire* Sloop of War which he commanded, in the 31st year of his age.

"Of Elizabeth Cook who died April 9th, 1771, aged 4 years.

"Of Joseph Cook, who died Sept. 13th, 1768, aged 1 month.

"Of George Cook who died October 1st, 1772, aged 4 months.

"All children of the first named Captain James Cook, by Elizabeth Cook, who survived her husband 56 years and departed this life 13th May 1835, at her residence, Clapham, Surrey, in the 94th year of her age. Her remains are deposited with those of her sons James and Hugh in the Middle Aisle of this Church."

A flat stone in the Middle Aisle (above referred to) bears the record—

"Mr. Hugh Cook,
Died 21st Decr., 1793,
Aged 17 years.

James Cook Esqr.,
Died 25th Jany., 1794,
Aged 31 years.

Also

Elizabeth Cook,
their mother,
Obt. 13th May, 1835,
Aged 93 years."

The inscriptions were previously unknown to me, and are not to be found in any books accessible to me. I therefore hope they may be of interest to members of this Society.

Footnote by Mr. Etheridge.—The first paragraph of this inscription was published by Lieut. C. R. Low, of H.M. Indian Navy, in a small work entitled "Captain Cook's Three Voyages round the World, with a sketch of his life," (London, Routledge & Sons, *n.d.*), p. 13, and the whole inscription appeared in "A Catalogue of the Collection of Relics of the late Captain James Cook, R.N., F.R.S., &c., (p. 7) that were exhibited at the Indian and Colonial Exhibition, London, in 1886, by Mr. John Macksell, one of the

surviving relations of Mrs. Elizabeth Cook, the great circumnavigator's widow. This cannot be looked upon, however, as a publication in the strict sense of the word, you are, therefore, as egards all but the first paragraph dealing with new matter.—R. E.

NOTES ON ANALYSES OF AIR FROM COAL MINES.

By F. B. GUTHRIE, F.I.C., F.C.S., and A. A. ATKINSON, Chief Inspector of Coal Mines.

[Read before the Royal Society of N. S. Wales, August 7, 1901.]

As there are very few analyses of the atmosphere of coal mines to be found in mining literature, the authors have thought that the matter is one of sufficient interest to the members of the Society to give the analyses of a few samples obtained from collieries in the State, briefly explaining the circumstances under which they were collected.

SAMPLES OF AIR FROM RETURN AIRWAY, WALLSEND COLLIERY.

The management of this colliery requested the miners to travel along the return airway to and from their work—this being much the safer plan—in order to keep them off the engine road; but it was alleged that by so doing the first general rule of the Coal Mines Act 1896 was infringed. The rule is as follows :—

"An adequate amount of ventilation shall be constantly produced in every mine to dilute and render harmless noxious gases to such an extent that the working places of the shafts, levels, stables, workings of the mine, and the travelling roads to and from those working places, shall be in a fit state for working and passing therein. The ventilation so produced shall be the supply of pure air in quantity not less than 100 cubic feet per minute for each man, boy and horse employed in the mine, which air (in

that proportion, but with as much more as the inspector shall direct) shall sweep along the airways and be forced as far as the face of and into each and every working place, where man, boy or horse is engaged or passing, main return airways only excepted."

The quantity of air was not called in question, and in order to test the quality in the return airway used as a travelling road, samples were collected as follows:—

Sample 1. From the Lambton heading return near the double doors, 184 yards from the engine plane. Time 3·50 p.m. Temperature 70 degrees F. Quantity of air passing 18,700 cubic feet per minute. This return airway receives part of No. 2 split, and the whole of Nos. 3 and 4 splits, and before passing through the working places comes down the Centennial shaft. It travels over 142 men, 14 boys and 14 horses, and consequently each man, boy and horse when travelling in this return at this place would receive 110 cubic feet per minute, if they were all in the return at the same time. The measurement of air was made about 100 yards from where the sample was taken.

A second measurement of air was made about 200 yards inbye (further into the workings) from the first measurement, and gave 25,280 cubic feet per minute, or 148 cubic feet for each man, boy and horse.

Sample 2. This was taken on another day in the place where the first measurement of air referred to above was taken, namely, about 100 yards inbye from where sample No. 1 was taken. Time 1 p.m. Temperature 72 degrees F. Quantity of air 19,320 cubic feet per minute, or 114 cubic feet for each individual.

Sample 3. This was taken on the inbye side of cross-cut, about 200 yards inbye from where sample No. 2 was taken. Time 1·45 p.m. Temperature 72·5 degrees F. Quantity of air 24,200 cubic feet per minute, or 142 cubic feet for each individual.

Sample 4. This was taken near the junction of Nos. 3 and 4 splits and about 300 yards from the working places. Time 2·10 p.m. Temperature 74 degrees F. The shade temperature at the surface taken at 3·30 p.m. was 75 degrees F.

Analyses of samples of Air.

No.	Oxygen.	Carbon dioxide.	Nitrogen.
1	20·03 per cent.	0·19 per cent.	79·78 per cent.
2	19·32 "	0·27 "	80·41 "
3	19·28 "	0·31 "	80·41 "
4	20·03 "	0·24 "	79·73 "

Tests, with negative results, were made in the mine for marsh gas by means of the Clowes' hydrogen lamp, which is able to detect the presence of 0·25% of this gas. If present, therefore, it was in less quantity than $\frac{1}{4}$%. Carbon monoxide was absent in all cases. The amount of moisture in the air was not determined.

Ordinary air was also examined by the same methods of analysis as were adopted in determining the oxygen and carbon dioxide in the above samples and gave :—

	Oxygen.	Carbon dioxide.
Ordinary air	20·9 per cent.	0·03 per cent.

The following table accordingly shows the deficiency in oxygen and the excess of carbon dioxide in the samples examined as compared with ordinary air:—

No.	Deficiency in oxygen, %.	Excess of carbon dioxide, %.
1	0·85	0·16
2	1·55	0·24
3	1·59	0·28
4	0·85	0·21

The quantity of carbon dioxide found in the worst sample (No. 3) is considerably below the amount found to be injurious in dwelling rooms. Professor Lehmann[1] quoting the results of some of the most recent investigations (1893) on this subject, shows that the presence in the air of dwelling rooms of 1 to 2% carbon dioxide causes only trifling symptoms after several hours.

Analyses of samples of air in collieries are not numerous. In the Transactions of the Federated Institute of Mining Engineers,

[1] Methods of Practical Hygiene, Translation by Sir W. Crookes, Vol. I., p. 276.

Vol. XVI, are some analyses by Dr. Haldane of samples of air from the return airways in the Hamstead Colliery, South Staffordshire, England, which are given in the following table:—

Road.	Distance from shaft in feet.	Temp. F. deg.	Deficiency of oxygen.	Excess of carbon dioxide
A. Main north return airway	150	74	0·37	0·10
B. North return airway	5,850	78	0·36	0·10
C. Return airway	7,920	80	0·77	0·26
D. Return airway	9,150	83	1·70	0·47
E. Main south return airway	150	...	0·24	0·095
C. Return airway	7,920	...	1·16	0·29
D. Return airway	9,150	...	1·20	0·33
F. Return airway	6,900	...	1·26	0·33

In comparing these results it may be pointed out that all the samples taken from the Wallsend Colliery were from the worst part of the return airway, and they cannot be fairly compared with samples A. and E. in the above table, which represent comparatively pure air close to the shaft. They compare favourably with samples C., D., and F., and are noticeably lower in carbon dioxide.

Analyses of air in return airways from other mines are to be found in the Transactions of the Federated Mining Institute.[1] These analyses show the air in these places to be of similar composition to that in the return airways at Hamstead.

On account of being safer, the return airways are often used in England as travelling roads, and it is fair to assume that the air in the returns so used does not differ materially from the samples above quoted, nor from the air in the Lambton heading of the Wallsend Colliery.

In one of the papers above referred to[2] Dr. Haldane shows that a considerably greater deficiency of oxygen and a corresponding excess of carbon dioxide can be borne before the breathing becomes noticeably deeper. The point at which the breathing was found

[1] Vol. VIII., p. 554, and Vol. XI., p. 272.

[2] Trans. Fed. Min. Inst., Vol. VIII., p. 557.

to be thus affected, was in air of the following composition, fire-damp being absent:—

Oxygen	15·30
Carbon dioxide	3·38
Nitrogen	81·32
	100·00

Referring again to the table of analyses from the Hamstead mine, the further point is to be noticed that the temperature in the Lambton Heading, Wallsend Colliery, was considerably lower; it was in fact from 1 to 3 degrees Fahrenheit lower than the shade temperature at the surface taken 1½ hours later.

Taking all the above facts into consideration, it appears, that although the air in the Lambton heading was not absolutely pure, it was not sufficiently vitiated as to be injurious to the health of those travelling in it.

The inconvenience complained of was probably due to the following causes:—

1. The distance to be travelled was considerable (1½ to 2 miles).
2. The walk was at the end of a day's work.
3. The men walk as rapidly as possible.
4. In going outbye, they are obliged to walk with the air current instead of against it.

Samples from Burwood Colliery.

These were taken in consequence of complaints received that miners suffered from headache whilst undercutting or "holing" the coal.

Sample No. 1 was taken from the face of main east cross-cut in the return airway near the Dyke. Time 12 noon. Temperature 76·5 degrees F. Air current about 16,000 cubic feet. per minute, for 48 men, 5 boys, and 5 horses; being 272 cubic feet per individual.

Sample No. 2 taken in No. 30 A bord, being the last in split and near return. Sample taken from freshly cut holing. Time 12·25 p.m. Temperature 79 degrees F.

Sample No. 3 taken from No. 32 A bord, being the fifth from the return end of the split. Time 12·55 p.m. Temperature 79 degrees F.

Sample No. 4 taken from No. 6 bord, Merewether's east boundary crosscut district. Time 1·30 p.m. Temperature 78 degrees F. Air current about 7,500 cubic feet per minute for 44 men, 4 boys and 4 horses, or 105 cubic feet per minute for each individual.

Analyses of samples from Burwood Colliery.

	1.	2.	3.	4.
Oxygen	20·42	20·77	20·83	20·34
Carbon dioxide ...	0·08	0·04	...	0·13
Nitrogen	79·50	79·19	...	79·53
	100·00	100·00	...	100·00
Deficiency in oxygen	0·48	0·13	0·07	0·56
Excess of CO_2 ...	0·06	0·01	...	0·10

Carbon monoxide and marsh gas were absent in all cases. Marsh gas was tested for in the mine by means of Clowes' hydrogen lamp. The determination of carbon dioxide in sample No. 3 was unfortunately spoilt owing to an accident, there being insufficient of the sample to repeat the experiment. The amount, however, was certainly no greater than was found in No. 2.

In the case of samples 2 or 3, the air cannot be said to be contaminated at all, and is practically as pure as the air in the streets of a town. In the other samples there is an excess of carbon dioxide and a deficiency of oxygen when compared with ordinary air, but not sufficient to produce ill effects upon anybody breathing it.

Samples of Air from Gunnedah Colliery.

On the 10th May, 1900, a fire was discovered in this colliery, about 200 yards from the tunnel mouth, in consequence of which it was decided to seal it off, in order if possible, to extinguish the fire. Whilst this was being done, an explosion took place, injuring several men engaged in the work of building stoppings, etc.

The work was again resumed and completed without further mishap. On the 10th August, 1900, the mine was reopened, prior to which the following samples had been collected from the stopping by means of pipe with tap:—

No.	Time of collection.	Carbon dioxide.	Oxygen.	Nitrogen.
1.	11·15 a.m.	1·46	15·88	82·66
2.	11·30 „	1·04	16·93	82·03
3.	12·10 „	2·09	13·68	84·23
4.	12·20 „	1·45	15·79	82·76

Carbon monoxide was absent in all samples, and also all inflammable gases. Sample No. 2 supports combustion, but the others do not. Prof. Clowes[1] states that air becomes extinctive to a candle when diluted with nitrogen, until the oxygen is reduced to 16·4%. This agrees well with the above observations in which only No. 2 with 16·92% oxygen was capable of supporting combustion. The carbon dioxide has little or no effect in the extinction of flame, in the proportions in which it is present in the above.

It may here be of interest to discuss the effects of the diminution of oxygen and the presence of different proportions of CO_2 and of black damp upon respiration and lights. By black damp is understood[2] the residual gas produced by the oxidation of coal. This has according to Dr. Haldane a fairly constant composition of 13 per cent. CO_2 and 87 per cent. N.

A candle flame is extinguished in an atmosphere consisting of oxygen and nitrogen only, when the percentage of oxygen is reduced to between 16 and 17 per cent. This mixture can, however, be breathed by a man without any ill effects, and it is not until the oxygen percentage has fallen to about 12 that the breathing becomes affected. According to Dr. Haldane[3] the breathing becomes deeper and more frequent, and the face bluish when the oxygen content is diminished to 9 per cent., at 5 per cent. loss of consciousness follows and death.

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[1] Proc. Roy. Soc., 1894, Vol. LVI., p. 2.
[2] Haldane—Trans. Fed. Min. Inst., Vol. VIII., p. 549, etc.
[3] Report on causes of death in Colliery Explosions, etc., 1896.

This report gives in a tabular form, the effects on man and on naked lights of varying proportions of these ingredients, from which we take a few figures to shew the difference in behaviour of carbonic acid and black damp. Carbonic acid in air affects the breathing when it is mixed with air in the proportion of 3·5 per cent. carbonic acid and 96·5 per cent. air, but it does not extinguish flame until 15 per cent. carbonic acid is reached, at which point initial loss of consciousness occurs. Black damp on the other hand extinguishes flame when 16 per cent. is present, but this atmosphere has no effect on the breathing which is not affected until nearly twice the quantity of black damp is present. If we put down the exact composition of these mixtures, the reason of this rather peculiar characteristic will be plain.

A mixture of air containing 3·5% CO_2 has the composition:—

			Effects on man.	Effects on light.
	Oxygen	20·17		
(A.)	Nitrogen	76·33	affects breathing	no effect
	CO_2	3·50		
		100·00		

A mixture of air containg 16% black damp has the composition:

			Effects on man.	Effects on light.
	Oxygen	17·56		
(B.)	Nitrogen	80·36	no effect	extinguished
	CO_2	2·08		
		100·00		

The breathing is affected in (A.) because of the presence of 3·5 per cent. CO_2 which has no influence on the light. The light is extinguished in (B.) because the oxygen has diminished to 17·5.

It is, therefore, clear that if the contamination is due only to diminished oxygen or to the presence of black damp, a man can breathe the air so contaminated at a point far beyond that at which a candle is extinguished.

Gases at Gob Fire at Greta Colliery.

Spontaneous fires have occurred at this colliery, and some years ago it was found necessary to seal off the old workings by means of stoppings. The gas examined was collected from one of these stoppings (a brick one) by means of an iron pipe with a tap. Temperature of air issuing from pipe 75 degrees F. Temperature of outside air 72 degrees F.

Composition of samples.

	Carbon dioxide.	Oxygen.	Nitrogen.
(A.)	2·14	10·50	87·36
(B.)	2·17	10·60	87·23

The gas instantly extinguished flame. It is noteworthy that these samples did not contain any carbon monoxide.

It appears interesting to discuss the question whether the samples of air obtained from Greta and Gunnedah as the result of fire contained any appreciable quantity of black damp, which latter, according to Dr. Haldane is the residual gas left on oxidation of coal by the air,[1] and is of fairly constant composition, containing about 13 per cent. CO_2 and 87 per cent. nitrogen.

In the case of the Greta gas, the residual after deducting the unaltered air contains 4·4 per cent. CO_2 and 95·6 per cent. nitrogen in the sample (B.), and 4·3 per cent. CO_2 and 95·7 per cent. nitrogen in the sample (A.), Neither of these approach the composition of black damp, but this may be due to diffusion or to incomplete oxidation.

Neither the Gunnehah nor Greta Collieries give off much firedamp, but the following samples show the composition of gases obtained from the Dudley Colliery, Newcastle, N. S. Wales, and Harecastle, England, both of which make firedamp, after being closed down in consequence of explosion and fires underground.

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[1] Trans. Fed. Inst., Vol. VIII., p. 563.

Sample from Dudley Colliery.

(Analyses by Mr. W. M. Hamlet, F.I.C., F.C.S., Government Analyst.)

Downcast Pit.			Upcast Pit.		
Carbon dioxide	3·2	per cent.	Carbon dioxide	2·8	per cent.
Atmospheric air	nil		Atmospheric air	15·0	,,
Fire-damp	96·8	,,	Fire-damp	82·2	,,
	100·00			100·00	

Sample from Harecastle Colliery.

(From Dr. Haldane's "Report on Causes of Death in Colliery Explosions."

Fire-damp	91·01
Nitrogen	5·93
Carbon dioxide	3·06
	100·00

THE THEORY OF CITY DESIGN.

By G. H. Knibbs, F.R.A.S.,
Lecturer in Surveying, University of Sydney.

[*Read before the Royal Society of N. S. Wales, September 4, 1901.*]

1. *Introductory*—The duty of designing and setting out an important city,[1] is one which, in the near future and in the ordinary course of things, will be cast upon the Commonwealth of Australia. An elaboration of the principles which should govern the design of such a city, and a statement of the several matters which call for systematic consideration in connection therewith, is therefore not inopportune. Neither is it of small moment. Such an office as the creation of a capital city, practically unhampered by any conditions of existing settlement, and

[1] The Federal Capital.

limited only by the topographical features of any selected site, is a unique one in the history of a country: the manner in which that office is discharged is of an importance which can hardly be overstated. A capital city, its general design, its utilitarian and æsthetic features, constitute an enduring index of the intelligence and foresight, the nobility of the sentiment, and the dignity of the artistic idea of the people creating it. The achievement must necessarily depend mainly upon two things, one the state of technical preparation, the other what may be defined as the moment of our æsthetic consciousness. Faultless technical knowledge is not in itself sufficient. It is, as it were, merely the *instrument* necessary for the proper realisation of the higher element; and if a city is to awaken in the beholder a distinct impression of its beauty, if it is to be in this respect one of the silent, subtle, but none the less high and powerful influences on the people who create it, and their descendants, then the artistic apperception, and the recognition of the dignity of the task, must be correspondingly vivid, and the outlook broader than would be dictated by mere utility.

The question of the normal elements of motivity I do not, of course, propose to discuss. The beauty and magnificence already realised in some cities are sufficient to remind us that no poverty of conception or present limitation should operate to make it forever impossible to create a beautiful city. It is therefore all-important that the city-designer shall take cognisance of what has already been attained, and further that as far as his instinct of prescience will allow, he shall anticipate the requirements and probable developments of the far distant future.

What I do propose to discuss, are those things that must necessarily command technical attention by way of preparation for what lies before a people when called upon to create a capital or other important city; and shall assume as given, a suitable site or sites, with its *sine qua non*, an abundant water-supply.

2. *General idea of a city.*—In order that the concentration of human activity, which is the essential feature of the aggregation

of human beings in a city, shall be of the highest efficiency, it is necessary that the lines of intercommunication between the buildings, forming as it were the real theatres of that activity, and also between them and the lesser centres of outlying territory, shall be the shortest possible, and therefore the most convenient. This is nothing more nor less than the affirmation that all systems of roads and streets should provide the greatest possible number of 'short cuts' from place to place, and thus economise as far as can be, human effort in the transaction of business, and in all other features of city life. The other element of importance is the appropriate localisation of the various types of industrial and other activity, so that the necessity for intercommunication itself, shall be reduced to a minimum. These two elements, viz., the street arrangement, and the determination of the purposes for which the blocks so formed shall be available, are the most fundamental in the development of a city-design. It is at once evident that both are greatly influenced by the topography of the site; a general disposition of streets and buildings which might be most suitable for one site, might be wholly unsuitable for another with different topographical features: any discussion of principles therefore can lead only to *general* results: these must, in any application, be taken as a general guide, to be modified as occasion demands. It is of course impossible to produce in detail an ideal design applicable to every site.

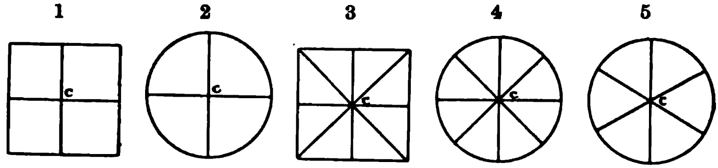
3. *Radial street-system.*—If one glances at any territorial map shewing towns and the roads leading therefrom to other similar aggregations of settlement, it becomes at once evident, that the lines of communication are on the whole *radial*, that is they tend to occupy the direct lines joining any one centre with those surrounding it: if diverted therefrom, it can be only because of topographical difficulties, or through the arbitrary interferences of the boundaries of real estate, or else from mere caprice. Any four centres forming, say a quadrilateral figure, would be united, not merely by the lines constituting the boundaries of the quadrilateral, but also by the lines forming its *diagonals;* at least unless

some element existed to hinder this. It is obvious from what has been said that the *rectangular system* of roads and streets so much in vogue in the States of Australia, is *inconsistent* with what may be properly called, not merely the natural position, but also the *position of maximum efficiency;* for to travel by any but the shortest way except for some adequate reason, is to waste effort.

Given a number of streets radiating from a centre, the shortest system of lines for connecting them one with another will be such as make equal angles with each radial pair: consequently the scheme of cross-streets, necessary to complete the radial system proper, will form a sort of ring-system, or else a polygonal system, like the lines on a geometrical spider's web.[1] This is not identical with a diagonal system, properly so called, as a reference to the illustrative figures hereinafter, Figs. 1 to 5, will shew. A definite

Figs.

1 2 3 4 5



numerical comparison of the relative merits of the various systems in respect to shortness of path of travel from place to place, may be readily obtained, and will serve to fix our ideas. The two squares, Figs. 1 and 3, and the three circles, Figs. 2, 4, 5, have the same area, the length of the side of the square therefore being $\frac{1}{2}\sqrt{\pi}$, when the diameter of the circle is unity. In each figure therefore the same area is commanded by the series of lines, which may be taken to represent streets. The two elements of importance are, (*a*) the total length of street to be provided, and (*b*) the

[1] This system was advocated by John Sulman, F.R.I.B.A., at Melbourne in January 1890. See his paper on "The Laying Out of Towns."—Aust. Assoc. Adv. Sc., Vol. II., pp.730 - 736. In particular, p. 732. It has also been advocated by J. Stübben, Baurath, Assistant Burgomaster of Cologne, in a masterly discussion of the question.—Das Handbuch der Architektur, Darmstadt 1890. See also Trans. Amer. Soc. C.E., Vol. XXIX., pp. 718 - 736, 1893.

mean distance of travel from all points to the centres, which are denoted by the letter C. The following table gives the results absolutely, and also in percentages.

I.—Mean distances of Travel and Total Length of Street.

Fig.	(1)	(2)	(3)	(4)	(5)
Mean Distance	·443	·446	·378	·348	·381[1]
Total Length	5·317	5·142	7·824	7·142	6·142[2]
Mean Distance %	100, say,	100·7	85·4	78·6	86·0
Total Length %	100, say,	96·7	147·1	134·3	115·5

On looking through this Table (I.) it is evident, first that (2) is better than (1), for while the mean distance of travel is increased only seven-tenths per cent., the total length of street is reduced about $3\frac{1}{3}$ per cent. Hence for similar areas the *ring* form has an advantage over the *rectangular*, in respect of reducing the total length of street to be provided in a given area, and consequently any *approximation* to the ring form will exhibit the same feature.

In order to shew more clearly the relationship between mean distance and total length of street to be provided, Table (II.) is computed, shewing absolutely, and also in the form of a percentage as compared with the rectangular system, the ratio of the total length of street to the mean distance of travel to reach the centre C.

II.—Ratio of Total Length of Street to Mean Distance of Travel

Fig.	(1)	(2)	(3)	(4)	(5)
Absolute	12·00	11·52	20·69	20·51	16·12
Percentage	100·0	96·0	172·4	170·9	134·4

A review of the figures in Table (II.) shews distinctly the advantage of (2) over (1); an angle of 90° is however too great between the radiating lines, so that any real consideration may be confined to (3), (4) and (5), that is to what may be called the 'diagonal' system, the octagonal-radial system, and the hexagonal-radial system. Comparing (4) with (3) it will be noticed first that there is a slight advantage for (4) in respect to the street

[1] The quantities are $\frac{1}{4}\sqrt{\pi}$, $\frac{1}{4} + \frac{1}{16}\pi$, $(\frac{1}{8} + \frac{1}{16}\sqrt{2})\sqrt{\pi}$, $\frac{1}{4} + \frac{1}{32}\pi$, $\frac{1}{4} + \frac{1}{24}\pi$

[2] Similarly $3\sqrt{\pi}$, $2 + \pi$, $(3 + \sqrt{2})\sqrt{\pi}$, $4 + \pi$, $3 + \pi$.

lengths: secondly that there is only half the number of acute angles (45°), so that the 'octagonal-radial' is distinctly preferable to the 'rectangular-diagonal' system. The most striking advantage is seen however in (5). Table (I.) shews that in respect of travel-distance it is practically equal to the diagonal system, and but little inferior to the octagonal-radial system; while in respect to street-length it is vastly superior to either: and still further, it gives altogether better angles, viz. 6 angles of 60° instead of 8 angles of 45°. We conclude therefore, that in order to secure the greatest advantage as to distance of travel, in a radial scheme of streets, the angles between the radiating lines should be approximately 60°, and that the cross-streets should be approximately symmetrical with respect to the centre: and further that such arrangement is to be preferred to the rectangular, so far at least as shortness of communication is concerned. This is very strikingly brought out on comparing (5) with (1). The total length of streets is increased only $15\frac{1}{2}\%$, while the mean distance of travel is reduced as much as 14%; in other words the reduction of distance of travel is practically identical with the increase of street-length! The radial system, pure and simple, has however some limitations which will be later considered, it is sufficiently clear that there should be points from which streets should radiate in all directions.

4. *Position of Radial Centres.*—The first point to be decided in elaborating a design for the streets of a city, is the position of what may be called its chief radial-centres, and its main lines of street. A concrete idea of what is meant by chief radial centres, would be reached by regarding such centres as the Capitol and the White House at Washington; or the Arc de Triomphe at Paris, between the Avenue de la Grande Armée and the Avenue des Champs Elysées. They may be defined as the centres round which either particular types of, or even general activity, will tend to concentrate, or they may be centres of æsthetic or intellectual interest, and it is obvious therefore that they should, as a rule, lie on the leading lines of communication between one place and

another: in fact the lines joining the centres, and the prolongations of such lines, ought to be the main arteries of traffic—the leading streets of the city. The position both of the centres and the main streets, are consequently dependent, partly on the topographical limitations of the site, partly on the position of outlying centres and the existing or potential roads and railways thereto, and partly also upon the suitableness of certain localities within the site for the special purposes or activities, for which provision must be made. The selection of the position of the chief radial-centres, requires therefore not only a comprehensive view of the administrative, educational, industrial, residential, military, and other needs of a capital city, not only a due regard for its communication with the outer world and for all the contingencies both in times of peace and war, which that communication involves, it requires also a nice appreciation of the topographical adaptabilities of the site, so that in the design the interdependence and mutual influence of every element shall be fully estimated and the general arrangement made the most convenient possible, and therefore the most economical; and further that it shall be such as will admit, without detriment, of that expansion which the future will certainly require. Upon an accurate perception of the best treatment of the site, the economy of the creation of the city will largely depend; and it is but proper that one should desire to have as perfect a result as possible for any given expenditure. This is a point to which we shall later return.

The grouping of activities having many points of contact, or common features, and the locating of one or more groups round a suitable point, as round a radial-centre, is so obviously desirable as to need no advocacy; and when a city can be designed without the embarrassments created by preëxisting occupation, there can be nothing to prevent such grouping, in any form conceived to be desirable.

Thus the housing of parliament, and of the great departments of official administration, might very properly be grouped around one centre, those having most frequent need of intercom-

munication being the nearest together: a university and its affiliated colleges might create another centre: technical and high schools still another: an aggregation of great commercial institutions yet another: and so on. Then again the industrial occupations which would develope, might with advantage be relegated to one quarter of the city, the large commercial houses to another, while the environs would normally constitute the residential sites, variously disposed according to the classes of residence allowed to be erected. The study, in the original design, should embrace all possibilities of extension for even remote periods, so far, at any rate, as they can be foreseen; and the control of settlement should also be sufficient to ensure the possibility of ultimate conformation to the first ideal, even if for any sufficient reasons it be temporarily abandoned.

5. *Combination of radial and rectangular street-systems.*—A rigid conformity to the hexagonal-radial system for the streets of a city, would constitute them three series of parallel lines, intersecting one another at an angle of 60°, and dividing the whole site into equal equilateral triangles, while the rectangular system consists of two sets of parallel lines intersecting at 90°, and dividing the area into squares. The greatest distance to be travelled in passing from any one point to any other, cannot in the former case be greater than the direct distance multiplied by the secant of 30°, nor in the latter than the direct distance multiplied by the secant of 45°. Calling the direct distance 100, the maximum distances of travel are

Direct distance	100·00
Hexagonal system	115·47
Rectangular system	141·42

It might be thought therefore that the advantage in favour of the hexagonal system is so pronounced as to exclude the adoption of the rectangular altogether. It has always been felt, however, that the rectangular system, has from the point of view of building construction much to commend it; it gives too, a better sense of orientation in regard to travelling through a city; hence it may

very well be combined with the hexagonal and other forms of the radial system. Again it may often happen that the convergence of only six roads upon one point is inadequate. For example, in Paris at the Arc de Triomphe there are no less than 14 avenues or streets converging, at the Place de la Bastille 10, at the Place de la Nation 9: in Washington at the Capitol there are 11 long convergent streets, and 8 and 10 in other places in the same city. When therefore a centre is of more than ordinary importance, it may be as the site of some great establishment or monument, or as the theatre of intense business activity, the number of convergent streets may be increased from say 6 to 12, and such a centre properly constitute a focus both of the radial and rectangular systems combined. The City of Washington is an illustration of the rectangular combined with the radial system, the former preponderating, see Fig. 6. (See Fig. 9 for polygonal radial system.)

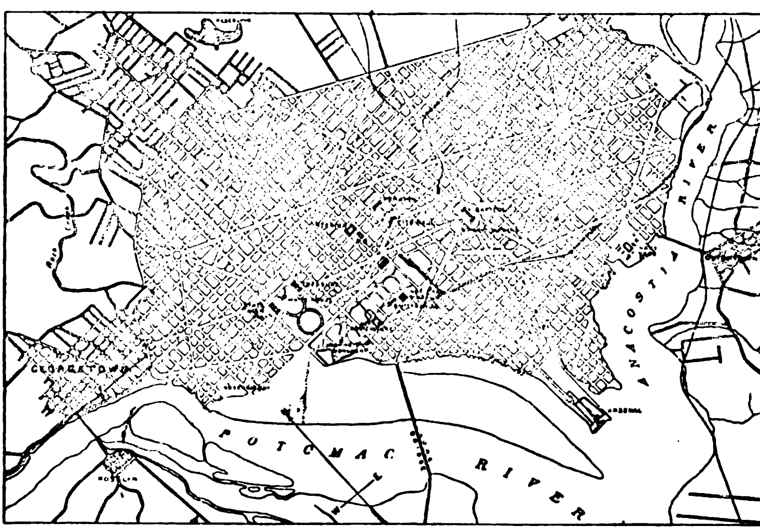


Fig. 6.

When it is considered that the importance of securing the full advantage of shortness in path of travel from point to point diminishes as the total amount of traffic in any street diminishes,

it will be realized that as long as the radial system is sufficiently employed for reducing the distance from all parts to the principal centres, and for bringing into prominence such æsthetic features as great public buildings and monuments, the substantial benefits of the system will have been secured. The adoption then of the rectangular system for the balance of the design, modified only under the compulsion of meeting topographical difficulties, will admit of the advantages of that system being also fully exploited.

6. *Curved Streets.*—On an undulating site, a strict adherence to any general and supposed ideal scheme for the system of streets is, as just indicated, often impracticable, because of the resulting severity in the gradient of some of the streets. Conformity to the fundamental design should therefore not be inflexible. If modifications of, or departures therefrom, will avoid the difficulty, there can be no valid reason for hesitating to make them, and such positions for the streets as would give uniform gradients might very properly be selected on conical hillsides, and round the heads of small valleys. This selection will involve the introduction of a *curved* form for the streets, and it may be occasionally, even the adoption of the zig-zag form. The use of curved streets is to be regarded not only as proper means for the alleviation of gradients, but also as an element in the design, capable of enhancing its merit as regards variety and artistic effect; especially in situations where traffic considerations are of less than average moment. The rigid adherence to straight streets and a rectangular system, characteristic of towns in the States of Australia, is a signal defect in the prevailing ideas of city-design: and its abandonment in favour of an independent treatment of each site, and an adoption of a radial-rectangular system would be distinctly beneficial even for villages. But to return to the question of curved streets. In situations where traffic is concentrated, where too, street rail and tramways are required, and where moreover the necessity of ameliorating the grade does not exist, curved streets are a disadvantage. Where a lengthy street view is effective, as bringing into prominence a great public building or monument, curved

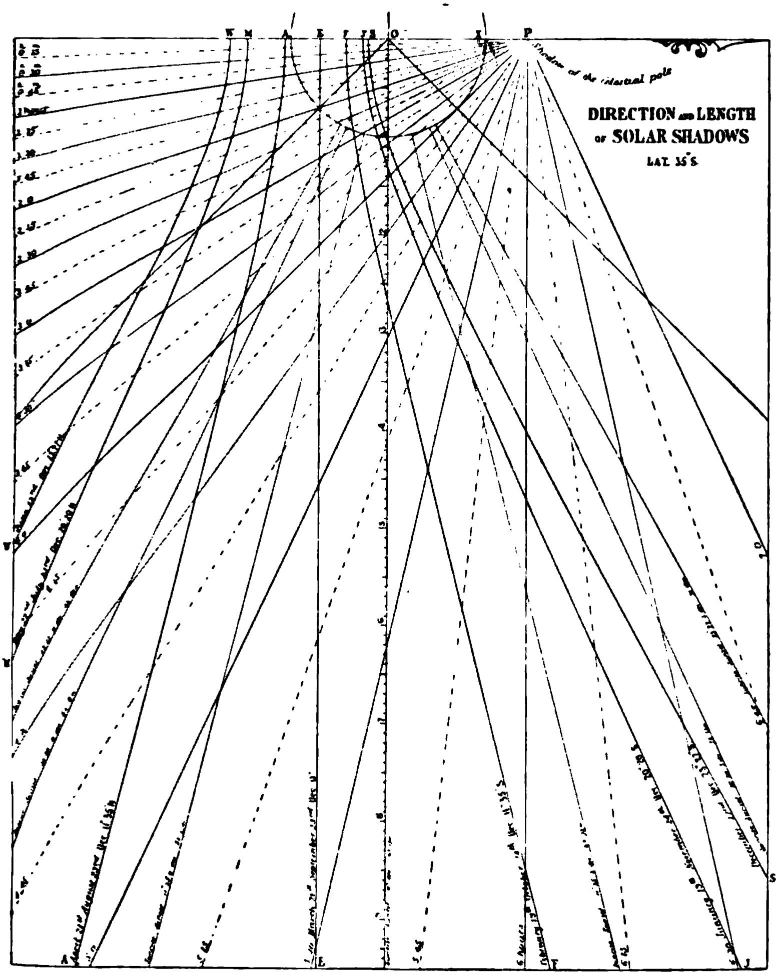
streets should also be avoided. It may here be noted on the other hand, that in an hexagonal radial system, if "ring-streets," as they have been called, are used to connect the radial lines (*e.g.* Fig. 5), there is a distinct advantage over a system of hexagons of the same area, the mean distance of travel to the centre being 8·25% more for the latter, Ring and curved streets may consequently be advantageously introduced, at any rate occasionally; and there can be no doubt therefore that they should form, if not a marked, at least a minor feature of any future design for a city.

7. *Cardinal direction of rectangular streets.*—The cardinal direction of streets, and for the orientation of buildings, is a question which must be studied in relation to the latitude of a site, and to the particular purpose to which buildings are to be applied. Between the tropics, the sun will occupy at some time of the year and day all points of the compass; his northern aspect for the whole year preponderating for places south of the equator, and his southern for places north thereof. Since in that zone his meridian altitude is great, and the meridian shadows are therefore short, the merits of a particular aspect have to be decided on somewhat different grounds to those which apply in temperate regions, where, as we depart from the tropics, there is a great disproportion between the whole lengths of the midsummer meridian-shadow, and the similar shadow in midwinter, and where also the sun at noon is not at one time north of the place of the observer, and at another time south.

With a view to more clearly illustrating the nature of solar shadows on a horizontal tract of land, Fig. 7 has been prepared, for the nearest 5th degree of latitude to that of this city (Sydney), *i.e.*, for latitude 35° S. The laws of position of the shadow of a vertical line may be thus defined for the temperate zone. For any one interval of time before or after *apparent* noon (*i.e.* the crossing of the sun over the meridian of a place) the terminals of the shadows on different days are points in a straight line which, produced, passes through a point defined by drawing a line from the elevated pole of the heavens through the top of the vertical line till it

meets the ground (supposed a horizontal plane at the bottom of the vertical line), the point P in the figure. For successive hours of the day, *i.e.*, before or after noon, the terminals of the shadows lie on the corresponding straight line meeting at this point. At the equinoxes, the successive positions of the shadow-terminal during the day lie on a straight line running east and west,

Fig. 7.



through the point defined by the terminal at noon, the point E in figure. At any other time, *i.e.*, between the equinoxes and the solstices, the shadow-terminals on any day lie on an hyperbolic curve, whose vertex is defined by the position at noon, and whose asymptotes intersect at the equinoctial point E.[1]

In the frigid *calottes*, or zones as they are called, the curves may become ellipses. Turning to the diagram, suppose a vertical line or pole to stand at O, Fig. 7, of the length, equal to OX, (*i.e.*, 1 foot or metre, or 100 feet or metres, or any other unit length): this vertical will be perpendicular to the plane of the page. In latitude 35° S., let the line OP be placed true north and south: then the shadow of the south celestial pole will be the point P; and the noon-shadow of the summit of the vertical, say of the length of 1000 units, will reach the following points on the days indicated:—

III.—Length of shadows at noon of a vertical of 1000.

Summer solstice.	Dec. 22	O – S	204
	Jan. 19, Nov. 24	O – J	262
	Feb. 19, Oct. 24	O – F	433
	Mar. 21, Sep. 23	O – E	700
	Apl. 21, Aug. 23	O – A	1057
	May 22, July 23	O – M	1446
Winter solstice.	June 22	O – W	1629

At the hours afternoon denoted by the lines radiating from the point P, the shadow will terminate at the intersection with the curves SS, JJ, etc.; that is to say, on the 22nd December the shadow of the top of the vertical line will move along the curve SS; on 19th January and 24th November along the curve JJ, and so on, the shadow reaching the intersection with the curve of the line radiating from P at the hour marked on the latter. If now a straight line be drawn from the point O to this intersection, it will shew the length and direction of the shadow at any particular hour after noon.[2] The morning shadow for the

[1] The declination change being disregarded, at least for each day.
[2] Measured of course by the unit height OX.

same number of hours before noon will be a similar line on the other side of the meridian line WOXP, that is to say, if θ_t is the angle of inclination between the south line and the shadow, for the hours before or after noon, then the shadows direction is, in the former case $180° + \theta_t$, in the latter $180° - \theta_t$. The shadows will never lie outside the curves SS and WW, which are, therefore, the limiting curves of the solar shadows.

Referring to the diagram it will be observed that there are *northerly* shadows in the morning and afternoon, in the summer interval between the equinoxes, *i.e.* between the 23rd September and 21st March, but none northerly in the winter interval. The shadows are respectively west and east at approximately the following hours of the day, for the different periods of the year opposite each.

IV.—Solar shadows east and west (approximate) lat. 35° S.

	Dec. 22 Solstice.	Jan. 19 Nov. 24	Feb. 19 Oct. 24	Mar. 21 Sep. 23
	h. m.	h. m.	h. m.	h. m.
A.M.	8·30	8·10	7·10	6·0
P.M.	3·30	3·50	4·50	6·0

If, therefore, a rectangular building have its sides directed to the cardinal points, then for six months of the year its southern wall will never have direct sunlight; so, also, the northern side of an east and west street. Table V, shewing the length of time the sun shines on the southern face of an E. – W. wall, brings this out more clearly.

V.—Length of time sun is south of east-west line, in either fore or afternoon. Lat 35° S.

Dec. 22 Solstice.	Jan. 19 Nov. 24	Feb. 19 Oct. 24	Mar. 21 Sep. 23
h. m.	h. m.	h. m.	h. m.
3·40	3·10	1·43	0·0

There is really no *effective* sunlight on the southern side of an E-W building for practically seven months of the year. Obviously the buildings and streets of a city should have as much direct

sunlight as any general arrangement will admit of, and the total absence of such for at least six months must be regarded as a serious defect. Nor is this fact modified by the necessity that may specially exist in some instances for deliberately avoiding direct sunlight. Evidently, therefore, the direction of the streets of a rectangular system should be placed in the N.E. and S.W., and N.W. and S.E. positions. The diagram will at once shew the effect of this, and the duration of direct sunlight on each face of a rectangular building, making angles of 45° with the principal cardinal points, will be as in the following table :—

VI.—Duration of Direct Sunlight in Lat. 35° S., on each face of a rectangular building set S.E., N.E., N.W., S.W.

Time of Year.	Face of Building.			
	S.E.	N.E.	N.W.	S.W.
December 22	4·50 – 11·10	4·50 – 12·50	11·10 – 7·10	12·50 – 7·10
Jan. 19, Nov. 24	5·0 – 11·0	5·0 – 1·0	11·0 – 7·0	1·0 – 7·0
Feb. 19, Oct. 24	5·27 – 10·33	5·27 – 1·27	10·33 – 6·33	1·27 – 6·33
Mar. 21, Sept. 23	6·0 – 10·0	6·0 – 2·0	10·0 – 6·0	2·0 – 6·0
Apr. 21, Aug. 23	6·33 – 9·27	6·33 – 2·33	9·27 – 5·27	2·33 – 5·27
May 22, July 23	7·0 – 9·0	7·0 – 3·0	9·0 – 5·0	3·0 – 5·0
June 22	7·10 – 8·50	7·10 – 3·10	8·50 – 4·50	3·10 – 4·50

The N.E. and N.W. faces have each eight hours of continuous sunlight : and the S.E. and S.W. faces have from $6\frac{1}{3}$ to $1\frac{2}{3}$ hours or a mean of four hours, which also is the duration of direct sunlight at the equinoxes. The signal advantage of this over the east-and-west and north-and-south positions needs no comment, and, since the case is similar in any part of the temperate zones, it may be affirmed that the cardinal directions of a rectangular system of streets should be inclined 45° to the meridian throughout that zone.

8. *Width of streets.*—The width of street desirable or necessary in different parts of a city is a question depending on various considerations. From the standpoint of economy of construction and maintenance, and from that of mere convenience in the conduct of business, the narrowest street that will serve the purpose, without intense congestion of vehicular and pedestrian

traffic, is the best. From the sanitary and æsthetic standpoints, on the other hand, wide streets are to be preferred; these too, do not subject pedestrians to acute danger in crossing, and the risk of vehicular accident is correspondingly reduced. If provision is to be made for future means of mechanical locomotion, street rail and tramways, greater width will of course be required, a fact which argues the desirability of seeing that the necessities of the future in this respect are liberally anticipated.

It is evident at once, not only that the streets should as a whole be somewhat narrower both in the intense business centres, and in the less important parts of the city and its suburbs, but also that the general character of the city must affect the question. Therefore in a *Capital* city the æsthetic requirements are rightly regarded as of commanding importance, and utilitarian considerations as secondary, and properly subordinated to the last possible degree consistent with the fact that the general arrangements must of course be really practicable ones. Speaking broadly, the towns of the Commonwealth have been designed with small regard to æsthetic features, and the idea of avenues constituting an ordinary feature is practically foreign to us,[1] though not absolutely so. The magnificent example however of Paris suggests the propriety of the greater radial lines from the chief centres, forming boulevards. It may be questioned whether such examples as the Boulevarts Richard Lenoir, or de l' Hôpital, or the Avenues des Champs Elysées, de la Grand Armée, or de Neuilly in Paris, the Boulevards du Midi, de Waterloo, du Régent, of Brussels, or the Unter den Linden in Berlin, can be lavishly followed. Still Australian experience has shewn that boulevards of considerable size[2] are appropriate and advantageous, and greatly enhance the beauty of a town.

Coming to actual dimensions, it may be said that lanes or streets of less width than say 10 metres or 33 feet ($\frac{1}{2}$ chain) are extremely undesirable. Unimportant roads and streets, so situated

[1] There are of course exceptions to this.
[2] *E.g.*, Sturt Street, Ballarat.

that they can never become of importance, might be designed with widths of from 20 to 25 metres, or say from 66 to about 80 feet. Roads and streets of moderate importance, likely to require tramways, cycle paths, central footpaths, and so on, might be of still greater width, viz., of from 30 to 40 metres, or say of from 100 to 130 feet; while still wider streets, set out with avenues of trees, flower-beds, etc., might have any width of from 50 to 75 metres, or say from 160 to 240 feet.[1]

With a suitable restriction as to height of buildings, such widths as have been suggested will not present any difficulties as to quantity of light, or as to suitable approach in cases of fire; while the abundant access of sunlight and the sufficiency of room for the planting of trees in the streets, makes it possible to ensure in the highest degree the fulfilling of the requirements of hygiene.

9. *Localisation of the various types of streets.*—Whatever care is taken, or however rigorous the control of occupation in the creation of a city, it is hardly practicable to ensure such a distribution as shall conform absolutely to that which might, having regard to the ultimate appearance of the city, be permanently sanctioned: to attempt it would, as a rule, involve excessive scattering of the population, or other injurious features. On the other hand any permitted departure from the distribution, deemed the best in the general interest, tends to establish itself, and there is the jeopardy that return to the original idea will be effectually resisted—a jeopardy that is by no means chimerical in a democratic community. This illustrates the signal importance of securing at the outset a disposition of the general settlement that shall practically accord with the ultimate intention, a result that involves not only the closest study of all the effects of the special localisation of the political, administrative, industrial, commercial, scientific, educational, residential, and military centres, but also an apperception of the reaction of each upon the other,

[1] The streets of Washington are from 80 to 120 feet, the avenues from 120 to 160 feet.

and a clear recognition of the possibilities of every practicable variation of the general design. Since the localisation of occupation involves localisation of the general characteristics of the *traffic*, and therefore of the *particular type of street* required, a methodical analysis of each possible variation of the design, in respect to its ultimate effect upon the health and appearance of the city, is essential in any attempt to guard against injury through the limitations of first or early occupation.

An important city is not mature even in a century; and the designer, if he is to leave a monument of the perfection of his work, in a general disposition which shall secure the possibility of it presenting permanently attractive features, must, while regarding everything from the standpoint of the remote future, regard it also in the light of present necessity, and only if his genius is equal to the task of harmonizing the two, will the result be satisfactory. During the first few decades it may be absolutely necessary, so as to suitably concentrate population, to allow development to proceed upon lines foreign to the ultimate intention, and to permit narrow streets to be substituted for wide ones. The design in such a case must contain an outline of such temporary modifications as cannot be avoided, in addition to the permanent features to which everything is finally to conform; and if settlement, on the lines of the temporary modification, be permitted only under clearly-defined and rigidly enforced conditions, ensuring return after a definite period to the original, no injury but on the contrary rather benefit will result, and one will not, as is so frequently the case, have to deplore the spoiling of the æsthetic possibilities of the site.

The interdependence of the types of occupation and of street, of settlement and of traffic, and the tendency of each to perpetuate itself without regard to the welfare of the city as a whole, involves, as we see, more than ordinary care in the arrangements of any city that is intended to be ideally beautiful, and no effort is wasted which has for its object the conservation of the higher

interests in such a way as to involve a minimum of alteration with its attendant expense and difficulty.

Outside such comprehensive considerations as the foregoing, the element of localising types of street depends solely upon their main function. For the leading lines of heavy traffic light grades are required, and widths proportionate to the ultimate magnitude of the traffic; special consideration is necessary to guard against inadequate provision at such points of congestion as depôts and freight-yards of all kinds, railway stations, and similar places. If the city is to possess a military centre, ample provision must also be made to facilitate the mobilisation and despatch of troops, war material, etc. The lighter traffic of merely residential streets involves less attention to gradient, their character depending solely upon their intended surroundings. For example, streets leading to each class of buildings would be designed in agreement therewith, those to be adorned on each side by palatial buildings possessing a collateral magnificence, whilst streets leading to localities populated by the poorer classes would be less pretentious; though they, too, might well be made picturesque with foliage trees.

10. *Grade and cross-section of streets.*—Ordinarily a grade of $\frac{1}{3}$ % in the longitudinal section of a street will suffice for surface drainage; for localities subject to tropical downpour this might be slightly increased, and where the rate of fall is unusually light slightly diminished. For vehicular traffic a grade of 10 % may be treated as a maximum, and that design which avoids heavy grades on the main lines of traffic is of course the best in respect thereof. In commercial and industrial, and even in residential parts of the city, the level of the streets may, with advantage, be 1 or $1\frac{1}{2}$ metres, say 3 to 5 feet, above the general level; on the other hand, in suburban residential localities, the street level ought to be the lower. The usual cross-section, viz., a carriage or roadway with raised footpaths, would, of course, in the case of the wider streets, be departed from. In the widest streets of all one part of the roadway might be devoted to heavy, and another

to light traffic, these being separated from the side walks by a row of trees on each side, while a central avenue or footwalk, with foliage trees on each side, would complete the section. Where there is little heavy vehicular traffic, strips forming garden or grass plots, lying between the footwalks and the roadway,[1] might constitute a feature. These could be graced also with shrubs of various kinds, and the centre of the street formed by a line or lines of ornamental trees, with or without footwalks. Roads and streets of less width would permit of a single row of trees on each side and next to the footwalks, or a single or double row in the middle. Cycle paths might well be introduced in many of the streets, in such positions as involve a minimum of interference with other forms of locomotion.

11. *Engineering features of streets.*—The necessity for some official control of the localisation of the different classes of occupation, which a regard for the general appearance and welfare of a capital city not only justifies but imperatively demands, permits its development to proceed on lines that obviate frequent changes in the constructional features of the streets; for these can all be thoroughly considered at the outset. The mains, conduits, tunnels, etc., required for water, gas, electric, or various forms of power-supply, for sewerage systems, for telephone and telegraphic services or for underground communication of any sort, can be located so as to involve the minimum disturbance of traffic, and the least expense for maintenance and repair; and the characteristic breaking up of, and injury to well-constructed streets, in order to reach such mains and conduits, can thereby be rendered an unknown element. Were it publicly realized how dearly we pay for our stolid ignorance and want of foresight in municipal arrangements generally, the constructional features of streets would perhaps be very different to what they are. In future city-design, the opportunity undoubtedly exists for avoiding that continual waste of resource, which, turned to advantage in more lavishly equipping

[1] Or, as in Washington strips may be left between the side walks and the property boundaries.

public institutions, and in making the city ornate, can be so much better expended. Similarly, an exhaustive consideration of the treatment of each street in regard to the necessity for tram or railways, will admit of the construction being developed on lines that avoid waste through the undertaking of various useless works, or injury to necessary ones. It will be a wise economy also to make the foundations of all streets thoroughly, and in no way to stint the means for so doing.

The scheme of lighting to be adopted, is an element in which decision antecedent to the development of the design is also requisite. Inasmuch as electric lighting does not involve, except at the generating station, any consumption of oxygen, and as the light itself does not produce those deleterious gases formed in the burning of coal gas, it is to be preferred wherever a start may be made *ab initio*.

More generally, it may be said that the predetermination of the whole of the engineering or constructional features for the streets is essential to the design being so elaborated as to reduce the expense to an absolute minimum, and it is only through the initial location of such features that everything dependent thereupon can be consistently and harmoniously adjusted and the best results attained.

12. *Sizes of blocks between streets.*—If in any site, the relation between the total area, and that to be occupied as streets, be antecedently assigned, the problem of ascertaining the size of blocks becomes numerically determinate, as soon as the general scheme for the streets is decided. In Paris the streets cover an area of about $\frac{1}{4}$ of the total: in Washington the ratio is still greater. With increase of street area, however, the construction and maintenance becomes correspondingly costly. The following suggestion as to suitable dimensions will sufficiently indicate the idea of general proportions:—

	Metres.
Public institutions, large factories, and large establishments generally	100 × 200

	Metres.
Large suburban residences with grounds	80 × 160
Larger business sites, city residences, etc. ...	60 × 120 – 160
Smaller establishments... ...	40 × 80 ; 30 × 60 – 90; 20 × 60
Workmen's dwellings	10 × 30

If smaller areas than these last are admitted the elements of hygiene and beauty must be correspondingly sacrificed. The length of blocks may vary between say 100 and 200 metres, or say between 330 and 660 feet, and rear lanes be from 10 to 15 metres in width, say 33 to 50 feet.

13. *Height of buildings.*—Apart from the impossibility of adequately dealing with fires breaking out in very high buildings, and the consequent jeopardy to property generally, and apart also from any consideration of the æsthetic defects of such buildings; a certain height may be regarded as injurious, as unduly limiting the sky-line, and as preventing sufficient access of direct and diffused sunlight to the properties in the neighbourhood. The following table shewing the lengths of shadow when the direction of the sun is 45° off the meridian, and the directions and lengths when it is three hours off the meridian, will afford the data from which a judgment may be formed as to the limits that may be considered reasonable, in restricting the height of buildings.

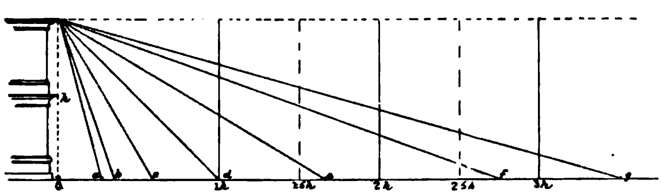


Fig. 8.

VII.—Lengths of shadows 45° and at 3 hours off the meridian, Lat. 35° S. vertical 100.

Date.	Dec. 22	Jan. 19 Nov. 24	Feb. 19 Oct. 24	Mar. 21 Sep. 23	Apr. 21 Aug. 23	May 22 July 23	June 22
45° off	27(*a*)	35(*b*)	59(*c*)	100(*d*)	166(*e*)	276 (*f*)	350(*g*)
3 hrs. off	86	90	107	141	197	273	314
Direction	86°	81¾°	71⅓°	60¼°	51°	45°	43°

Fig. 8 shews the position of the solar-shadows when the sun lies N.E. or N.W. for the different months of the year; the shadow reaches the point *a*, *b*...*g* at the dates specified in table. The positions of the shadows on buildings, with streets of various widths, is also shewn.

If a street have buildings immediately abutting on it, equal in height to its width, the maximum angle of sky transversely to the street is 53° 8′, and the minimum 45°.[1] A skyline higher than 45° is clearly too high, hence as a maximum limit, the façade of any building abutting on the street should not be of greater height than the width of the street. The façades will be better seen with a less angle, a two-thirds limit would, therefore, be preferable, *i.e.*, the height to be not more than two-thirds of the street width. Buildings standing back from the street frontage could be correspondingly increased in height. This element will be further considered in dealing with the æsthetic elements of city design.

14. *Theory of aspect.*—The most favorable form for picturesque effect in a site would be a gently undulating surface, surrounded by commanding hills, constituting a sort of semi-amphitheatre.[2] The desirable aspect in relation to the cardinal points will depend very much on local peculiarities, such as the climate, the prevailing direction and character of the winds, and similar meteorological factors. Consequently it is hardly possible to generalise in respect thereof.

So far as mere sunlight is concerned, eastern slopes are cooler than western, and northern than southern; consequently northwestern slopes are to be preferred where heat is desired, and south-eastern when the opposite is the case. These effects may, however, be greatly modified by other factors.

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[1] Max. = Observer in middle of street. Angle $= 2 \tan^{-1} \frac{1}{2}$, *i.e.*, 53° 8′. Min. = Observer at side of street. Angle $= \tan^{-1} 1$, *i.e.*, 45°:

[2] See report by Messrs. Mansfield, Vernon, Barlow, and the writer, p. 28 of the report of the Commissioner on Sites for the seat of the Government of the Commonwealth.

In a city set out on the rectangular-radial system almost every possible orientation in respect of individual blocks exists, and if the site be also undulating, choice of aspect in such a system can offer no difficulty, because of its multitudinous variety. So that whether industrial or other requirements demand the presence or absence of direct sunlight, those requirements are easily met. Buildings in which it is necessary to secure the maximum penetration of solar rays, so as to benefit by their heat in winter, and the minimum penetration so as to avoid the heat in summer, should so far as the geometry of solar shadows is concerned, have their long axes east and west in southern latitudes and their windows on the north face of the building. Since, however, the temperature reaches a maximum after noon through the cumulative effects of the sun's heat rays, the axis should, theoretically, be rotated slightly, so as to turn a little to the north on the east side, therefore a little to the south on the west side. The amount of this rotation can be ascertained by taking account of the difference between the apparent noon and the times of maximum temperature; the differences between the noon and maximum temperatures, and the latitude of the place considered, the discussion extending over the changes for an entire year, so as to properly integrate the effects, and hence deduce their mean. The necessary rotation will, however, not greatly modify the E. - W. position for the axis. The designer must, it is evident, take account of these necessities, and for buildings of a large size, and requiring spacious grounds, where aspect is important—as for example hospitals, sanatoria, etc.—provide suitable blocks.

15. *The æsthetics of design.*—A study of those examples of architecture which impress the human consciousness with a sense of beauty, has revealed the fact that their general proportions, and the mutual relationship of their details, conform to simple numerical ratios and to an harmonious scheme. These ratios, spatially realized in the cube, square, the plane or circular equilateral triangle, the 3, 4, 5 triangle, the sphere, cube, pyramid, etc., are geometrical forms that constitute, as it were, a skeleton

on which architectural features are developed, in symmetrical grouping, with however such relief in detail as to obviate too cold and severe an effect, or what may perhaps be called an appearance of excessive symmetry. The proper subordination in the various parts of structures of their mass effects is also essential to awaken that impression of stability and repose which, together with grandeur of form and beauty of outline, and the grace of harmonious ornament, constitute the ideal of architectural design. Although these matters require the immediate and intense attention rather of those charged with erecting the buildings of a city, than of those whose function it is to design its streets and general arrangements, the latter can by no means neglect them. A knowledge of, and attention to æsthetic laws are absolutely necessary in studying a design, for as the eye passes over the contoured plan of a proposed site, the artistic possibilities of every feature must array themselves before the consciousness of the designer, if his work is in any way to exhaust them.

Outside the æsthetics of Architecture proper, the designer requires moreover to consider, in general, the picturesque effect of masses of foliage, the perspective appearance of monumental buildings and monuments from the points of view where they will be prominently seen, the grouping of buildings and classes of buildings, the effective position for parks, gardens, etc., the spatial provision necessary for the proper viewing of all features of interest, and so on; for it is by attention to such elements of city design that the possibility of beauty is created, and the picturesque capabilities of a site are exploited. Thus eminences and concave surfaces, both of which lend themselves to striking effects, should be exhaustively studied in relation to the general scheme.

16. *Sites for monumental buildings and monuments.*—The two classes of site that give the necessary prominence to monumental buildings are the summit of hills and the centres of amphitheatres: the one bringing a building into relief against the sky, the other shewing it in relation to its surroundings. In both cases the preservation of space about the building greatly enhances its

effect, by ensuring for it a sufficient distinctness. Remembering that a considerable time must elapse before any great city can be completed,[1] the reservation of sites for future public buildings and requirements generally, and for extension of buildings as the necessity arises, should always be on a most liberal scale, as this not only avoids the need for costly resumptions of land, but also enables the æsthetic effects to receive that adequate consideration which they rarely do if the element of cost is serious.[2]

The spatial provision for monuments, intended to be of noble proportions, therefore, would be appropriately located at prominent radial centres, while that for those of lesser size would be relegated to more unpretentious positions. It is, of course, important that the magnitude of monuments should harmonize with their surroundings; and as the form they may be expected to take depends very largely upon the contingencies of the future, the spatial provision should be liberal. The essence of the whole matter is that all conspicuous or prominent sites should be appropriated for those great public buildings and monuments upon which a people may be expected to lavish its wealth and artistically express its national feeling.

In order that monuments of all kinds may be properly seen, an unobstructed area must be preserved immediately round about them. For viewing detail, an onlooker would stand at a distance from the monument about equal to its height; to see it as a whole, at a distance about twice its height; to see it with its background and immediate surroundings, at say three times its height;[3] and to see it with its general surroundings at a still greater distance.

[1] It will, for example, be many years before Australia will be wealthy enough to erect truly monumental buildings. It would be well to commence, however, on permanent lines, whenever we do start the *substantial* buildings.

[2] The penalty paid, over and over again, in the States of the Commonwealth, for want of foresight in the matter of public requirements, is not merely a most serious financial loss: the possibility of *adequately* meeting those requirements has practically vanished.

[3] Angles 45°, 26° 34′, and 18° 26′ respectively.

It is necessary, therefore, that about every monument the unobstructed space should be between a distance equal to its height, and that equal to at least three times its height. Similar monumental buildings of noble proportions should stand back a sufficient distance from the street to admit of their being favourably seen.

17. *Treatment of streets from the standpoint of æsthetics.*—Owing to the fact that great lengths of street, especially when unvarying in width, of similar section, and fairly level, produce on the beholder a sense of wearisome regularity, the introduction of spaces for monuments, large street fountains, water-jets, foliage squares, etc., at such points as relieve the view, is a desirable corrective. It is hardly possible to lay down any rule as to the length which may be unrelieved, because so much depends upon grade, width, and general treatment in other respects; a length of from 15 to 25 times the width might be taken as a general indication. Tiresome uniformity can also be avoided by subjecting each street to independent treatment, so that each may possess some characteristic. Even alteration of width is preferable to excessive symmetry, and may be introduced to counteract its unæsthetic effect.

The undisguised presence of telegraph wires, telephone cables, etc., besides being unsightly, is a menace to public safety in cases of fire. Overhead electric wires in a tram-system although perhaps less unsightly, are inconsistent with a fine effect, and might well be transferred to underground conduits, as has already been done in some instances.

It has been said that monuments, so too, foliage masses, may be employed as a relief to street uniformity: they may also be introduced to obviate the ugly effect which arises from the disappearance of buildings etc., over the summit of streets crossing a ridge, for in no case should such effect be unrelieved: their proper situation is of course central, the traffic passing on either side, on a sufficient space provided therefor.

If monuments be erected in curved streets, the concave[1] is the proper side, forasmuch as it has the greater area of visibility, and

[1] That is the side of greater radius.

moreover the concave side forms an effective background, as is evident on viewing figures in niches. The convex is less effective than even a flat background, to say nothing of the reduction of the area of visibility. Hence spaces for monuments are desirable on the concave side in effective localities.

The lighting arrangements of a city are also susceptible of artistic treatment, and lamp-posts or candelabra could be so designed and arranged as to greatly enhance the beauty of streets. The necessity of occasional illumination might, with advantage, be systematically considered, and such permanent installations made as would admit of its more frequent use. This applies no less to the illumination of buildings than to streets, and the expense of permanent constructions would be scarcely greater than the cost of individual illuminations. In streets planted with trees, the effect could be made very pleasing, and the somewhat wanton injury to this formation, common on such occasions, wholly avoided. All these matters may easily be taken account of in the development of the design; they should not be an afterthought, however. The same remark applies to the form and position of drinking stands, pillar boxes for letters, telephone fire alarms, conveniences, letter-boxes, and other furniture of modern streets; all need to be considered in the design, so as to be made harmonious with their surroundings.

Among places admitting of decided improvement as regards the usual treatment, may be mentioned street intersections. Where the blocks have acute angles, a sufficient cut-off to form a façade, or a suitable rounding off, greatly enhances the appearance, and even the intersections of rectangular streets are markedly benefited by similar treatment. The customary right angle is far from satisfactory æsthetically. The cutting off of corners increases of course the diagonals at the intersection, and since the side-walks or footpaths follow the outlines of the blocks (*i.e.*, are equidistant from the building lines) increases diagonally, also, the roadway proper. This enlargement leaves room for street ornamentation at the intersections of the centre lines. By making

the cut off of corners adequate, provision may be made for a small square, a monument, clump of foliage, or small garden. A still greater cut-off will permit of a central square, circle or ellipse of finer proportions, with roadways round it, and which may be utilized for a more pretentious central feature, and the independent treatment of every intersection will produce a gratifying result.

In addition to those at street intersections, spaces are also desirable in front of, and in some cases even on three sides of, certain types of public buildings, especially those in which the architectural elaboration would not normally be restricted to the front, as, for example, museums, theatres, churches, etc. Arcades and approaches thereto are features which, since they can be made very effective in appearance, ought to be provided for in the design; and further, sites should be indicated for those fine pieces of sculpture or architectural art which the artistic sentiment of any cultured people will eventually require. Since all artistic elements must stand in harmonious relationship to one another, and their distribution be such as to give them a maximum efficiency in relation to their influence in beautifying the city, they ought all to be considered in the original design, so that the necessary provision may be made. The usual practice of either entirely neglecting, or inadequately regarding these matters, and then doing the best possible with the sites that chance to be available, can never be satisfactory, as is obvious when one contemplates the all too common hopeless disfigurement of what were originally ideally perfect sites.

18. *Public parks and gardens.*—Public parks and gardens are not only an ornament to a city but a necessity to its people, if their health is to be regarded, and considerations of health and beauty may at least have weight in important cities.[1] Hence we are justified in making liberal provision for public gardens,

[1] The antagonism of interest between the estate vendor and the public good should be guarded against. The price paid for cupidity on the one hand and ignorance on the other is serious.

irregular surfaces are to be preferred, as giving the landscape gardener greater scope for displaying his art, and as possessing intrinsically greater charm. In selecting areas for public gardens therefore, the irregular tracts would always be chosen, provided other parts of the design could be made to accord therewith, and provided also that the positions lent themselves to good effects from every point of view. Whole blocks, or even double, triple, or quadruple blocks, containing suitable features might therefore be devoted to the purpose, the distribution over the entire site being made fairly uniform, but adapted to the general character of the surroundings.

Besides these gardens and smaller parks, in the city proper, large parks also are necessary for its environs. The Bois de Boulogne, and the Bois de Vincennes of Paris have each an area of over 2,000 acres, and similarly liberal provision for every important city is to be desired. Parks like these would constitute recreation or picnicking grounds for the peoples of the cities and their areas ought to be ample for the probable ultimate population of the city. The creation of artificial, if there be no natural, lakes, especially for cities not on the sea-shore, would be advantageous, and if the water supplied to them were, on its passage, passed through large fountains of many jets, not only would the feature be very attractive, but the water itself would also be well aërated. By suitably selecting the path for the conduits conveying this water, it could in some cases be made to serve either all or most of the fountains of the city, passing by gravitation from one to the other, subject only to the loss by evaporation at each fountain.

I may be here excused for repeating a suggestion made to me in conversation by the Commissioner appointed to report on the sites for the Federal Capital.[1] If the parks were thickly planted with trees whose foliage was beautiful, and whose timber at the same time was of value, then when the demand for the fuller use of the parks arose, necessitating clearing, the trees would have become a valuable asset, and the income from the timber available for removal might be made to materially assist in the more

elaborate development of the parks. Another suggestion made by the same gentleman is that the parks might to some extent illustrate the types of timber to be found scattered over the face of the earth, not by individual specimens, but by creating small forests of such type.

19. *Hygienic elements of design.*—It is not only in the choice of a site that the elements conducing to health need to be studied. However wisely the choice may have been made in respect of climate, of the nature of the surface and subsoil, of the condition of the discharge of surface waters, and the position of the ground-waters, of the possibilities of adequate water-supply and efficient drainage, there still remains a need for a hygienic as well as æsthetic control of the localisation of settlement. And since this reacts upon the whole question, it is not possible to omit the hygienic elements in elaborating a design that is to be as perfect as our knowledge will allow.

The first great requisite to general health is the prevention of all settlement on those parts of a site where undesirable hygienic conditions prevail. For example, neither residences nor factories should be allowed to be built or established in depressions or other places where the moisture is excessive, or where water is liable to accumulate in heavy storms. A complete defence against the liability to misapplication of such areas is the converting of them into parks, and planting with types of vegetation that make a maximum demand upon the available moisture. By planting and draining, an area can be quite transformed, both in character and appearance, as the history of the city of Washington, U.S.A., so well demonstrates, and an unsightly feature may be converted into one of beauty.

A second requisite is that so far as possible variations in the design permit, those should have weight which lend themselves to convenient and efficient drainage systems, both for storm waters, and domestic, industrial, and other polluted drainage; and the

[1] Alexander Oliver, Esq., M.A., President of the Land Appeal Court, State of N.S.W.

outlines of the scheme for this should therefore be fully considered *when* the design is being developed, and not *afterwards*.

The third requisite is that the total quantity of breathing space provided in the design should be large, the vegetation made abundant; and when the building stage is reached, the necessary sanitary provision enforced for every structure, overcrowding being prohibited by requiring a sufficient number of cubic metres of space to each inhabitant.

And among the most important of the hygienic elements, I would place that of ample provision for play or recreation grounds in connection with every school, college, or other educational establishment; *i.e.*, a complete abandonment of the present niggardly notion of what is a reasonable provision in this respect. That the recreation of a people should be under pleasant and healthy conditions is always important, and never more so than in the case of the young, so that the school-grounds of a beautiful city should in themselves be a source of attraction, and exhilarant in their reaction upon those who use them.

Similarly hospitals and sanitoria should have bright surroundings and pleasant aspects, for the cheery and tonic effect of these is by no means the least potent of the remedies available to those charged with the care of our health.

The suitable location of industrial occupations which are either noxious or unpleasant, even in a minor degree, is a matter of importance in enhancing the merits of a city, and in dealing with those occupations as they arise, all provisions for diminishing their mischief should be enforced. For example, since a smoky cannot be a beautiful city, at any rate in the highest sense, all smoke in factories ought to be consumed. Where industries are such that they cannot be ameliorated, they can be excluded from the city proper. Therefore provision for abattoirs, and similar establishments are preferably omitted. These and similar malodorous occupations, can be concentrated at some convenient but sufficiently distant point, for though they may not directly create

sanitary mischief, their reaction upon human beings is unfavourable, and they are therefore undesirable.

20. *The preliminaries of design.*—Imperfect as is the statement given of the elements to be considered in any real attempt to properly design an important city, it will nevertheless be sufficient to indicate that a preliminary topographical and contour survey of the whole of the site is an *essential.* Such a plan perfectly represents the surface, and if supplemented with geological information as to the depth at which rock is found, the nature of the rock and of the material from the surface down thereto, it would constitute the necessary prerequisite for thoroughly discussing the design. Obvious as this seems, (and it must be equally evident that even in regard to the engineering details alone, the cost of obtaining such information would be far more than compensated by the aid it would lend to economy of construction) it has not been the practice in the Australian States to obtain it. The time lost in so doing is gained in the end, and it is only by such systematic procedure that satisfactory results can be achieved. I am well aware that those who have not thoroughly studied this question, are under the impression that what is called the common sense of well educated people is sufficient for the task of designing. That is not the opinion of those who have seriously given the matter their professional attention. If evidence were wanted of the calamity of indifferent design, it is to be had in our own city and suburbs. The topographical features of Sydney would have permitted it to be, if not the most, at least one of the most beautiful cities of the world. No word-painting could too vividly, or with too high a colour, express the magnificent opportunity that once existed for the people of this land to create a city of almost unparalleled beauty: that opportunity has been hopelessly lost through the ignorance, and want of apperception of those whose duty it was to avail themselves of it, leaving at the same time a monument of the dignity of their ideas. And the reason of failure is that no great scheme for the creation of the city was ever heartily entertained. Like Topsy it has 'growed.' And any

other city that grows by chance will equally exhibit great imperfections, and fail of its possibilities.

21. *Conclusion.*—The treatment of the subject of this paper, is by no means exhaustive, and may be taken rather as a general indication of its scope, than as a systematic and complete presentation. In concluding I may be permitted to express my indebtedness to the paper by Herr J. Stübben (Baurath, and Assistant Burgomaster of Cologne) on the same subject, and to that by Mr. J. Sulman, read at the Melbourne meeting of the Australasian Association for the Advancement of Science, more than ten years ago (1890). Both advocate the radial-ring system. As to the adoption of the radial element there can I think be no question; and I have shewn the great advantage of the ring system. This system may in my opinion well form a feature relieving the uniformity of the rectangular, but since all three can be employed with advantage, it ought not to be dominant. A complete and final abandonment of the present practice of lightly regarding the matter of city design, and a really exhaustive study from every possible point of view of any selected site, as a preliminary qualification, is what is desired. Given this, we shall have in each case a noble and far-seeing design, and the cities of the Commonwealth will bid fair to be all that we could wish, so far as the art of city building is concerned. And unique among them should be that which will be known as the Capital of Australia.[1]

[Added 12th Sept.] Since writing the above my attention has been called[2] to an article on "City Plans" by Horace Bushnell, D.D. Essay V. in his "Work and Play."[3] He affirms that there can be no absolute plan for cities, each must be designed by itself. The essay is an exposition of the subject from the standpoints of convenience, health, and artistic development. Although the

[1] May I add that it would be easy to introduce and familiarise the people with the metric system, which must inevitably be adopted, if all the measurements, dimensions, etc., are given for the Federal Capital in that system.

[2] By Mr. J. H. Knibbs. [3] Lond., Alex. Strahan & Co., 1864.

scheme of treatment greatly differs from that just given, and although on minor matters there is some slight difference of opinion the fundamental ideas are as nearly as possible identical, making allowance for the fact that certain elements now require attention, which did not exist when the essay was written (1864), and that experience has accumulated since then. I am reminded also[1] that Karlsruhe might have been quoted as affording an example of the radial-ring system of streets. Lastly, I wish to

Fig. 9.

make it absolutely clear that the ideal design must be founded on the radial element, the rectangular, and ring systems, and curved or zigzag streets being *combined* therewith, so as not merely to suitably conform to the topographical features, but to do so in such a way that in respect of convenience and of imposing effects, the city will be as perfect as possible. In Fig. 9 above, I have given an existing example of ring or polygonal streets; it is part of New Orleans.—G.H.K.

[1] By J. Marden, M.A., LL.D.

Discussion.

Mr. H. G. McKinney, M. Inst. C.E.—The paper is very comprehensive in its character and bears every evidence of careful thought and skilful preparation. Any criticism therefore which I have to offer relates to matters of detail and to the order in which action should be taken.

The first point to which I feel disposed to take exception is the place given to the paragraph devoted to the preliminaries of design. I concur in Mr. Knibbs' opinion that "a preliminary topographical and contour survey of the whole of the site is *essential*," but I should have preferred to see this point brought in near the beginning of the paper and greater prominence given to it. The site selected for the Federal Capital is almost certain to be in hilly country, and the contour of the ground will be a factor of the first importance in settling the character of the street system or systems, which should be adopted. Examination merely of the headings under which Mr. Knibbs has discussed the subject shows how much depends on the contour plan. For instance the important question of the positions of radial centres is one which will depend in a very large measure on the natural outlines of the ground, as will also the question of the advantage or propriety of adopting curved streets.

As the immediate object in view in establishing the Federal Capital is to provide Houses of Parliament and offices for the use of the Federal Government, it appears to me that all other objects should be subordinated to this. I quite concur in Mr. Knibbs' opinion that all possibilities of extension should be provided for, but I think that in attempting to make definite provision for various possible developments there would be some risk of losing sight of the main object which should be kept in view.

In his statement regarding the fixing of radial centres, I think more stress might be laid on facilities for water supply and drainage, and on the location of railways and main roads, but Mr. Knibbs may very justly say in regard to this, that the magnitude of the subject compelled him to condense his remarks.

Mr. Knibbs very justly condemns what may be termed the so-called "Practical Man" principle in regard to laying out the Federal City. There can be no doubt that the best professional advice should at the outset be obtained regarding the surveying, engineering, architectural, sanitary, and horticultural questions which have to be dealt with in founding a model city.

Mr. HERBERT E. ROSS, B.Sc.—Mr. Knibbs certainly seems to have assembled all the general elements which should determine the design of an ideal city. The consummation of such a design is, however, so beset by the dangers of democratic interference that if only a major part of the theory outlined could be carried into effect the result might well be regarded as a distinct milestone in the march of civilization. Of the difficulties of realization, the greatest would of course be an impatience leading to amendments of the conceived design, sacrificing future perfection to more obvious present expediency, so that continuity of purpose should be an important element in the theory.

The radial-ring arrangement of streets is doubtless the best possible economically, and perhaps even æsthetically, it has a minor objection however, it would tend to a sense of confusion of locality in the ideas of an average citizen ; a common instance in our own city is afforded by the irregular system of streets surrounding our Government administrative buildings. Of course the radial-ring arrangement, with rectangular subsections, could be systematised to avoid this difficulty to a certain extent, by the streets being named according to consecutive numbers, or other series, and referred to centres or to some popular meridian, thus establishing relative location throughout. The principle of concentration of allied interests is good only to a limited extent. Thus, for instance, the association of administrative systems, and again commercial activities, would be desirable and necessary, but the principle would fail if applied, for instance, to educative institutions, except those which claim the whole attention of their votaries. Thus museums, libraries, and the representative collections of art and industry, should be conveniently scattered in the centres of greatest

activity, and not set apart where the work-a-day world would gain least from their civilizing influences.

In the adoption of curved streets or indirect routes to avoid heavy grades there must be some mean condition, a compromise, as it were, between the direct route of the steep gradient, and the devious route of the easier grade. The author's proposal that the maximum grade under these circumstances should be 10% is considered quite excessive; a maximum of $7\frac{1}{2}$% under the most unfavourable topographical conditions would entail no special difficulties, and certainly should not be exceeded. The economy of low gradients extends far beyond the immediate section of road considered, and may sometimes determine the load at a distance.

Any plan having been duly decided upon, I consider it would be highly dangerous to the satisfactory final completion of that design, if any allegedly temporary amendment be permitted, especially where the building line is concerned. It would be quite in the economy of a design that streets be wide and yet not wholly in use. A central strip for instance, not paved and treated as a shrubbery, would entail no great cost, and even if subject to neglect would be better than some other excuse for permanently crippling the design.

Of the broad question of æsthetics there is much to be said, and the general principles should never be lost sight of, as they are independent of all accidental features which form only the framework for their application. Starting, *de novo*, it would be possible to introduce principles impossible and unknown to the cities of the past, which have, as Mr. Knibbs graphically puts it—like Topsy—growed. Of these, to my mind, one of the greatest possible æsthetic importance is the question of the weather protection of footpaths. There is nothing associated with the habitations of man so fatal to beauty in design, so hideously excrescent and foreign to every canon of architectural proportion, as the street awning. It is necessary to every climate and is disowned by every style of architecture. The architect excludes it from his drawings, knowing the while, that parasite-like it will attach itself

to his building before it leaves his hands. The street awning can have no place whatsoever in a beautiful city; and yet under the special conditions under which a new city may come into existence it would be an easy matter to supply its place, and at the same time add new possibilities to the beauty of our street architecture. To this end I would so regulate the conditions of land tenure that there would be two building lines to the side of each street, one line would lie, say, one third the width of the footpath from the kerb thereof, and the other or near line would be back at the full distance of the footpath. An invariable condition of building in certain streets would result in two-thirds of the footpath being under cover and one-third open. Instances of this class of construction in this city, though not so applied, are afforded by Victoria House in Pitt Street, and the General Post Office. Such construction is conformable to every recognised style of architecture and would undoubtedly lend itself to fine effects hitherto impossible.

Mr. Norman Selfe, M. Inst. C.E.—To discuss within reasonable limits such a lengthy and masterly paper as that which Mr. Knibbs has contributed to this important subject, is very difficult. I therefore propose to supplement rather than to criticise; and to make a few prosaic remarks on some of the commonplace aspects of the question, hardly touched by Mr. Knibbs, but which naturally occur to those who are in daily contact with the practical rather than the theoretical side of such matters.

It seems to me to be entirely premature for any one to dogmatise on the subject of the Federal Capital, before certain definite and important premises have been thoroughly settled. As a result of having looked upon fifty or sixty of the principal cities of the world—from Stockholm to Naples, and from Boston to St. Louis, it has been forced upon me that those cities are all the results of special series of combinations of conditions—unique in every case. Prague and Chicago, London and Christiania, what have they in common? Philadelphia, one of the largest cities of the world, appears to be one of the least self-assertive;

but, like its brother Chicago, it owes much of its stateliness and beauty to conditions that, so far, have not arisen in Australia.

If the Americans are the sharpest business people in the world, they have also developed patriotic instincts to an extent and in a way totally unknown in this southern land. There speculators and capitalists have purchased and subdivided immense areas around their cities. They have laid out broad avenues, with promenades and intervening parks; the latter containing winter gardens when necessary, to preserve their flowers and delicate plants through an inclement season. This has been done by means of Trusts, whose object was not mere vulgar money making, but the more noble one of securing for all time to its members, faultless residential districts, in combination with the most beautiful and healthful surroundings. Few if any such works have yet been undertaken here, even if such a spirit is animating the wealthy public men of the Australian States. If there is such a desire abroad among us there is some doubt as to the scope for its operations in connection with the Federal City.

Before we can deal very much with the site of the Federal City we require to know :—First as to Official Buildings—

(*a*) Legislative Buildings and Vice-Regal Residence.

(*b*) Public Offices of State : as Mint, Treasury, Customs and Internal Revenue, Patents, Military and Naval Departments, etc.

(*c*) Supreme Court and Law Departments.

(*d*) The residences of the principal Officers of the Commonwealth, whether such are to be simply private homes or State mansions to serve as foci for ceremonial functions.

(*e*) The shops and magazines of trade required to supply the wants of the official staff and its servants.

(*f*) The homes of the various grades and classes of servants other than those housed in the public buildings; and every accommodation that appertains to the machinery of government.

Secondly, Non-Official Buildings.—Prior to taking any steps with regard to colleges, art galleries, museums or libraries, and before any provision can be made for a non-official population, some determination must be arrived at as to the likelihood of others than the Members of the Senate and House of Representatives—(*a*) taking up a permanent residence in the district, or (*b*) paying occasional visit to the city. A permanent non-official population can only grow under one or both of two heads. In the first case the mineral, agricultural or forest resources of the district may be of a character to warrant and favour the establishment of manufactories, and the position of the city as a centre of trade may favor the economical distribution of its goods; then an industrial population may be reckoned on. Or the site may have such beautiful salubrious and economical attractions as to lead to the city becoming a resort for families of means.

It is necessary to consider in any selected site whether any of its natural features should be emphasised or suppressed. For example, a foreground of water, whether river, lake, or creek, although insignificant in the original landscape, might be so altered by embanking and terracing as to become a characteristic feature of the city.

As regards the relative merits of a rectangular hexagonal or radial and circumferential street system; nothing could posibly be settled beforehand, about a site that will in all probability be in hilly country. The only safe rule is that which provides that there should be the shortest practicable routes between the most important centres. In old cities we find straight cuts being continually made, with such an object, through slum districts. If there is only one prominent elevation on the site, it should no doubt be crowned either by the Citadel (if there is to be one) or by the Capitol buildings without the Citadel. There should be plenty of park and garden surroundings, and if the main centre is too elevated for direct radial roads of approach, then spiral avenues may be necessary. If there are lesser or subordinate elevations, then other State or prominent buildings should crown

them; and every endeavour should be made to prevent concentration into too narrow a focus for a commencement.

While on the subject of parks, greens and open spaces, a custom which obtains in many cities of the United States may be referred to. It is no unusual thing in that great country to see public parks, the domains enclosing State Capitols, the grounds surrounding the mansions of the wealthy, and even the gardens bordering the stately rows of villa residences, on their tree lined avenues, all entirely without gates or enclosures of any kind. A great deal has been said about Washington, D.C., and it is certain that any authorities that may be appointed, will not forget the lessons to be drawn from it; but the great difficulty will be to design a nucleus, with all the possibilities for expansion and extension, which will not be what—"the city of magnificent distances" was —a ragged and disjointed one for a generation or two at least. When however, the positions of the streets are once settled on, their borders planted and their roadways formed, then no other authority than that charged with their maintenance, should be allowed to pull them up again. We should insist that subways should be imperative in the principal streets of the Capitol.

Mr. J. H. MAIDEN.—Having had no time to make a set report on the subject I can only offer a few remarks at present on my colleague's valuable paper. I trust that the Federal City will not, at an early stage (or indeed at any other), be overloaded with too many fine buildings. A beautiful building need not necessarily be a costly one and it is to be hoped that free use will be made of bricks of various tints and colours, of tiled and shingled roofs, of wooden outside beams, and other architectural features of wood. In our sunny climate we particularly want lightness, brightness, and colour, particularly in our domestic architecture; any excess of brightness can be toned down by creepers or by judicious plantings. The presence of large quantities of building stone does not commend itself to me, in this connection, so much as abundant supplies of first-class brick clays.

Some of the fine buildings that have been suggested by various writers should be looked upon as ideals, perhaps not to be reached before the lapse of many years. It will be found, when the work of forming the city is set about in earnest, that the inevitable expenditure will be enormous, and therefore we should carefully discriminate between the essentials (as laid down in Mr. Knibbs' paper) and those suggestions which have been made without due consideration of ways and means. We must remember the vicissitudes of national finance, that the good ship of State at irregular intervals strikes a rock, and then retrenchment is the watchword. Retrenchment is often carried out in a more or less empirical way, and we should guard against the sacrifice of essentials in such a contingency. Washington is a city often quoted to us as an example, but we should not lose sight of the fact that it has a far wealthier and more densely populated territory at its back than we have.

I would suggest that the whole of the Federal territory be looked upon somewhat in the light of a gigantic park, the streets and the buildings to be inserted as details and when required. By this I mean that one grand scheme should be kept in view, that all our energies should not be entirely devoted to the official and residential part of the Federal City to the neglect of its suburbs and of its adjacent territory. In planning the roads and other means of access to the Federal territory we should not lose sight of the fact that the design of the city itself, which is of course of supreme importance, should not exclude rational treatment of the federal non-urban territory.

Design your streets and squares and gardens as soon as you can, and then let the planting begin. You will get more evident results from an artistic and hygienic point of view from planting than by any other means, and planting, amongst other advantages, will give definiteness to the ground plan of the city. There is an old proverb "Trees grow while we sleep"; while other details are being worked out our plants are increasing in size and usefulness. I trust that the crescent will be adopted to some extent, as it is

capable of very artistic treatment. The crescents should have segmental plantations between them and the busy highways. Crescents in London, Edinburgh, Leeds and other cities, small and great, will readily occur to members.

Then there should be a supervising architect to pass all plans of buildings before erection. I do not mean merely as regards compliance with sanitary bye-laws and safety of construction, but in regard to taste. The supervising architect should be an arbiter of taste, and while his ideals would not be too high, they should be high enough to prevent any gross offence against taste.

Coming to matters more particularly within my own province, let preparation be deliberately made for the planting of trees by the sides of streets. Is there a street in Sydney where this has been done? Or a noble avenue in New South Wales? The planting of a tree is not the careless making of a shallow hole and the off-hand putting of a tree therein. We must have good soil and good drainage. If the former is not there already, we must obtain it. No trenching or planting of the permanent avenues or plantations should be done by contract. When we plant a tree we do it for all time and therefore no inducement should be offered to do anything which would contend against success in this direction. Everyone has experience of irremediable loss,—perhaps of money, certainly of valuable time, inflicted on citizens who have only discovered bad planting by its after effects in wasted years.

Amongst public bodies often a labourer is told off either to plant or to tend trees,—a policy that shows that the gardening profession has not attained proper recognition in New South Wales. As a very general rule the citizen calls in the services of a skilled tradesman to satisfy his requirements, as he knows that such a policy is wise, and the truest economy, but the exception he commonly makes is in regard to his garden. If a man has tried everything else he can still be a gardener; this is an economic heresy which is very widespread in Australia. A good gardener is a trained man and one who has frequently undergone a long and severe apprenticeship, and it will be in the truest interests

of this State and of the Federal territory when public opinion is so educated that the value of a gardener is properly appraised. Much useful work can be done by the garden-labourer or the navvy, under skilled supervision, but the technical skill of the gardener must be employed for planting and its attendant operations, for pruning (some people think that fruit-trees alone require to be pruned), for prevention of disease and for the application of sprays and other technical methods for the arrest of disease. These may seem details, but they are essential, and I invite attention to them with all the earnestness of which I am capable.

The prospect of noble avenues of trees in the Federal City is very pleasing, and I trust that nothing will prevent their extensive adoption. As compared with the results, the expenditure is certainly most justifiable. The value of the avenue, whether along streets, along approaches to buildings or as promenades in parks, has been but little realized in Australia, although common enough in Europe. And let me enunciate an axiom "One avenue one kind of tree." The finest avenues in the world consist of one kind of tree, as by that means uniformity of growth and general appearance, which gives the main charm to an avenue, can be alone secured. The pernicious misplaced hankering after variety which causes so many avenues to be spoiled because they are of two or more kinds of trees is responsible for the disreputable appearance of so many avenues and boulevards. Such remind one irresistibly of the "awkward squad."

I would extensively plant fruit-trees (which might be the property of the hospital) along the boulevards, and then the eye would be delighted with the prospect of a magnificent display of blossom in the spring. In the fruit season the public could be educated to respect the crop; this has been done in France. If the work were properly done it should be at least self-supporting.

Then clumps of trees and shelter belts from the west and south should be extensively planted, or, if they are there already, very stringent regulations should be adopted in regard to the felling of trees by irresponsible persons.

We have no grand Arboretum in Australia, and the foundation of the Federal City gives us the opportunity of establishing one that should be fully availed of. This would be of ornamental appearance and of great interest to the average citizen; it would also be of high value from an educational point of view. The growth of timber trees here would be a matter of deep interest to the Forest Departments of the different States, which would probably join to partly or entirely support it.

Mr. Alexander Oliver has suggested a geographical arrangement of trees in the large urban or suburban plantations, an excellent idea that has much to commend it. But I am very anxious to see the trees, in such plantations, arranged in Natural Orders also. For example, what a grand and useful thing a Pinetum would be —when we could get every species of Pine (with other Conifers adjacent) we could secure and compare their growth. The Oak plantations, collected from species indigenous to the United States and Mexico, from Europe, from the Himalayan region and from China and Japan, could become a feature in the Federal City that would attract many pilgrims. The cost would not be great and the economic lessons would be important, and we must let these two points always be with us in regard to the city, otherwise the Federal expenditure will be unduly inflated.

Personally I only plant young trees,—so, if my advice were followed special lines of trees could be raised from seeds or cuttings while the surveyors were putting in their pegs.

I was much struck with the model village of Port Sunlight[1] in England, where there are allotment gardens at the backs of blocks, the houses being arranged in a more or less quadrangular method for the purpose. Here is a hint for such gardens at the backs of blocks in the town lots for workmen in the Federal City. Incidentally let me commend the neat, pretty and various domestic architecture at Port Sunlight, much of which could be introduced, with but little alteration into the Federal or other Australian city. I show you photographs in order that you may see how light and

[1] The creation of Lever Brothers and Company.

bright it is. At Port Sunlight, as you will see, great use has been made of lawns from the houses and other buildings to the roads, the lawns or gardens being protected by light iron railings where necessary.

And finally, let us encourage hedge planting in lieu of railings wherever possible. The Federal site will be not less than 2,000 feet above the level of the sea and the selection of approved hedge plants for that elevation is very great. Hedges can be made most artistic adjuncts to buildings, and, what is very much to the point, they are inexpensive.

JUDGE DOCKER—When the discussion upon Mr. Knibbs' paper was adjourned I also resolved to take part in the debate, as the subject is one in which I have taken a great interest, and as I have already expressed some views upon it in a letter published in one of the Sydney newspapers during the latter part of last year. But having read Mr. Knibbs' paper, I find myself in the same difficulty as Mr. McKinney. I find that the author has taken up and discussed every point, in a far more forcible manner than I could hope to accomplish, inasmuch as he possesses the technical knowledge which I do not. So it only remains for me to reiterate, and if possible, emphasise one or two of the points already insisted upon.

1. After the site for the Federal Capital has been selected and a contour survey made, an ideal of the city as complete must be evolved before a stone or a brick is placed in position. It ought not to be left to a single mind, however gifted, to create this ideal city, but a large commission should be appointed, including, not only the most distinguished engineers and architects of the Commonwealth, but also artists and other specialists, whose contributions towards elaborating the general ideal might be valuable. It is difficult to conceive of a higher honour than to be a member of such a commission and to share in the task of evolving the ideal of a Capital City as clear and distinct as was the vision of the "New Jerusalem" to the inspired Seer, but which will take decades perhaps centuries to realise.

2. I approve of the combination of different systems, the rectangular, the radial, the crescent; modified of course, by the contour of the surface. I think the nucleus should be rectangular and of considerable extent; and the transition to radial streets could be conveniently made by taking the diagonals of squares for the sides of a series of larger outer squares, the half-squares left by this transition should be reserved for such public or semi-public buildings as ought to be detached from other buildings and surrounded by plantations or open spaces. I wish to insist particularly on the necessity for leaving ample open spaces for recreation etc., not confined to one locality, but distributed uniformly through the occupied area. In fact, my idea of the general plan of the city may be illustrated by a chess board. Building should be permitted only on the alternate squares, the others being occupied by gardens and plantations, such as outlined by Mr. Maiden, artificial lakes and numerous recreation grounds for cricket and other sports.

I should like to touch upon many other points, but I do not wish to occupy the time of the meeting by going over matter which has been already so thoroughly and so ably discussed by Mr. Knibbs in his paper, and I will conclude by complimenting him upon the admirable manner in which he has accomplished the task he has undertaken, and by expressing the hope that he may be a member of the commission which I trust will be appointed to evolve the ideal of the Federal Capital.

Professor W. H. Warren, M. Inst. C.E.—I congratulate my friend Mr. Knibbs on having produced a very complete and thoughtful paper. I am sure the various subjects which he has dealt with at some length will be of great value to those whose duty it will be to arrange for the proper laying out of the Federal City. I am acquainted with all the important cities in America and Great Britain, as well as those of France, Germany, Austria, Italy and Hungary, and I am thus able to fully realize and appreciate the value of the various matters brought forward in the paper.

Mr. Knibbs assumes that a suitable site is available, and he places first the fact that an abundant source of water supply is

available, to which I should add, of suitable quality, within a moderate distance so that the cost of the necessary works, whether by gravitation, pumping, or a combination of these will not be unreasonable, or at least fairly economical. With an abundant supply of water available at a reasonable cost, a system of sewerage and drainage can be readily designed.

As to the relative merits of the rectangular and radial systems of laying out the principal lines of communication: these have been clearly dealt with, but it is impossible to deal with this matter more definitely until the site of the proposed city is actually selected. When this is done, I consider that the physical features of the country will indicate the most suitable sites for the main public buildings, and the most desirable combinations of the rectangular and radial systems of streets connecting these important buildings with the remainder of the city. Such cities as Washington, Paris, Berlin, Vienna, and Budapest give valuable suggestions on this head.

The cardinal direction of rectangular streets in regard to the latitude of the site has been very fully considered, and I do not propose to add anything to this part of the paper, but in regard to the width of the principal streets, I consider that there should be ample room for a double line of tramway with a thoroughfare on each side for vehicular traffic, and ample width for footpaths. In the main street of the city leading up to the principal Government buildings, I consider the plan adopted in the Unter-den-Linden of Berlin would be most suitable, as it provides completely for all kinds of traffic, and the rows of trees would be most useful in summer, and add to the beauty of the street. Even George Street near the Town Hall is not wide enough for the principal street of a city such as Sydney.

It must always however, be considered that very wide streets, such as King William Street, Adelaide, involve considerable expenditure in construction and maintenance, where the traffic is heavy. There is a practical economical width which should be obtained in every case wherever possible, which depends upon the

nature of the street, the height of buildings, and the amount and kind of traffic. The tendency to construct increasingly lofty buildings and the necessity for electric tramways, both involve the construction of wider streets than were formerly required. I consider that a single row of trees should be plánted next to footwalks or a double row in the middle of all the principal streets.

Engineering feature of streets.—The chief point to be kept in view is to avoid divided authority and as much as possible the construction and maintenance of the streets of our Federal City should be concentrated in one authority, which should control and maintain whatever tunnels and subways were required for telephone service, water supply, gas, sewerage and electrical conductors for power and light, so that there would be no possibility of the traffic of the street being interfered with to an unnecessary extent, and the various disturbing elements of this nature, which we are all so familiar with in Sydney, would be avoided, with all their unnecessary expenses and inconveniences to the public.

Again, I see no reason why electricity should not be exclusively used for tramway traction, light, and power, so that there would be no real necessity for gas, or for the hydraulic system of transmitting power such as we have in Sydney, as all the various matters dealt with under this head could be more efficiently and economically provided for by electricity, and the smoke nuisance would be minimised. Incidentally I consider that measures should be taken to stamp out the smoke nuisance, now that its prevention is better understood. I quite agree with the necessity of public parks and gardens, from the utilitarian, hygienic, and æsthetic aspects of the question. The discussion cannot well be carried much further until the site of the city is selected, and then the real work may be commenced in which the principles dealt with by Mr. Knibbs and brought out in the discussion, may be applied in a practical manner.

Mr. JAMES TAYLOR, B.Sc., Wh. S., etc.—The paper we have heard from Mr. Knibbs is so well prepared that very little room is left for criticism. One little matter has occurred to me in reading it

through since last meeting. Mention is made of the establishment of manufactories in the city. No doubt such establishments must arise sooner or later in connection with a large city, and in grouping them as suggested in the paper, attention should be paid to prevailing winds, so that the manufactories would be placed as far as possible, towards the lee side of the city.

There is another matter I would just like to notice, although it does not perhaps, strictly speaking, come within the limits of Mr. Knibbs' paper, *i.e.*, the location of the site. We are hearing a great deal about this subject just now and I have made a calculation on the subject as follows:—If we suppose the population of each of the Federated States to be concentrated in its capital city and consider each capital to be a heavy point having a weight proportional to the concentrated population, the heavy points being rigidly connected: then the centre of gravity of the system of heavy points thus formed should give the position of the Federal City. Or, other things being equal, the suitable site nearest the point thus determined should be adopted. The site thus indicated would be situated about Lat. 35° 30′ S., Long. 147° 20′ E., say about thirty miles south of Wagga Wagga.

Mr. HENRY DEANE, M.A., M. Inst. C.E.—Referring to the recommendation of a previous speaker, that an area should be set apart for manufactures, Mr. Knibbs had not included this as a necessary provision; and rightly, too. Manufactures, if possible, should be rigidly excluded from the Federal City area. They were not wanted there and there was plenty of room elsewhere for them.

With regard to the remarks of one speaker, that the city should be under one control so as to avoid the evils that had arisen in Sydney through different authorities breaking up the streets at different times, to lay pipes and make other improvements; the City Council would probably not have done any better had they had full charge of affairs. The Federal City would have chances that Sydney never had. It would of course be under one central control, either the Federal Government itself or a suitably selected Commission, and it could be laid out with subways for pipes, etc., and all modern improvements from the start.

"RECURRENCE OF RAIN,"

THE RELATION BETWEEN THE MOON'S MOTION IN DECLINATION AND THE QUANTITY OF RAIN IN N. S. WALES.

By H. C. RUSSELL, B.A., C.M.G., F.R.S.

[With Diagram.]

[*Read before the Royal Society of N. S. Wales, September 4, 1901.*]

YOU may remember that on June 3rd, 1896 I read before this Society a paper on the "Periodicity of Good and Bad Seasons," I stated "that I had not found time to investigate the question of the moon's influence upon weather, some of which I had only so far investigated." The interval between these papers has been spread out with the duty I had to give to official work, but I have got so far that it seems at least one part of the evidence is conclusive, and fortunately I have found it possible to put the most important parts in the form of a diagram, so that these parts can be seen at once. I think when you have read what follows, you will be induced to believe that the moon must have something to do with the occurrence of rain, however much the other opinions may have been discarded, because here the changes in the rainfall are undoubtedly coincident with the positions of the moon; and you will not be asked to believe any statement I may make, but simply to look at the diagram. However, we will return to this again, and in the meantime describe the way in which the diagram was made. I first carefully studied our rainfall, and found that inland the rain diagrams gave a very different prospect to those on the coast. The inland following clearly in cycles of nineteen years, while those on the coast were irregular. The reason for this I found was due to storms coming over sea and depositing rain water in such quantity that they did not bear any proportion to those inland. In other words, whereas inland the monsoonal and winter rains came to us, as parts of the regular offshoots of

the Equator, and are therefore subject to regular distribution, the rains that came on to this coast are often made up of hurricane storms, offsets of equatorial hurricanes of great severity, and therefore are associated with abundance of rain.

Attempts to plot in diagrams side by side, the storms of the coast and inland made evident at once the irregularity of coastal rains, and I therefore confined my investigation to the longer records of those inland stations, and I could not but regret that my predecessors had not begun the duty of measuring rain long since. Some few stations in Riverina had fortunately been started there, which assisted very much, more especially one at Horsham, Victoria, where the observer began to record rain in 1848; our first record at Bathurst began in 1858.

With the object of eliminating possible errors in the older records, I have as far as possible, taken the average rainfall of neighbouring stations, for instance Bourke and Charlton, Bathurst and Burrundella (near Mudgee), Yanko and Urana, Murray Downs station (near Castle Donnington) and Wanganella station. From all these I have taken the *total rainfall* for each year, and in accordance with the scale—5 inches of rain to each vertical space —I have plotted them in, year after year in their proper order and length. The thick vertical lines between 1850 and 1851, 1869 and 1870, 1888 and 1889, are 19 years apart, and it was at once evident that it divides these records into natural spaces, in which the first 6 years had abundance of rain. More conspicuously is this evident from Yanko and Urana, but it is also a feature in the other lines, and then follow a long series of what has been called "the dry period," which we *are now in*. For in this present cycle, the first bad year of the series was 1895 with a poor amount of rain, which was dried up by hot N.W. winds, and made the period one of very serious loss, and from that on we have had a most serious drought. From the year 1895 to the end of 1900, we have lost twenty-five millions of sheep by starvation, in addition to the death of all the increase during the past six years, which

in good years would have amounted to about twenty millions of sheep more.

Now turning to the diagram of the moon, it was made in this way: the extreme south position of the moon for *each year* was selected as a convenient way of shewing the motion in declination and marked on the diagram representing that year, and year after year the moon's extreme declination was plotted on these lines, ultimately all the points were joined together and made the curve you see, which simply indicates the extreme south distance of the moon from the equator each year; and during the southerly motion of the moon for six years there is abundance of rain. Then drought begins, not wholly for want of rain, but in many cases because we have strong N. to N.W. hot winds; a feature which does not appear when there is plenty of rain.

I do not mean to say that I have demonstrated that the moon is an active point in the weather, but I think, seeing the rain is shown so clearly to come in times of abundance, when the moon is in certain degrees of her motion south, and when the moon begins to go north, then droughty conditions prevail for seven or even eight years, a phenomena repeated for three periods of nineteen years each, that it is either a marvellous coincidence, or there is a law connecting the two phenomena: I am convinced that there is some connection between the two.

On the RELATION BETWEEN LEAF VENATION and the PRESENCE of CERTAIN CHEMICAL CONSTITUENTS in the OILS of the EUCALYPTS.

By R. T. Baker, F.L.S., Curator, and Henry G. Smith, F.C.S., Assistant Curator, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, October 2, 1901.*]

One of the results of our research on the Eucalypts of New South Wales, is, that we are able to show that there is a marked agreement between the chemical constituents occurring in the oils and the venation of the mature lanceolate leaves of the several species, thus forming the genus into fairly well marked groups. It was not until the investigation of the greater portion of these oils had been completed that this fact began to develope. The direct bearing of the leaf venation in the several species of Eucalypts had not previously been demonstrated, although it has been customary to incidently refer to it in the original descriptions. We think that it has now become necessary to more fully describe this venation in the future if accuracy of specific characters is desired.

The reproduction of the venation can be carried out very well by photography alone, so that it is unnecessary to diminish the accuracy of detail by drawing, If the quite fresh leaves be photographed directly upon the paper, using the leaf as a negative, and placing in strong sunlight, an excellent reproduction of the venation is obtained, and the most delicate reticulation, together with the oil-glands (in those species where they are prominent) is well seen. This detail can be reproduced by well known photographic methods.

The venation of Eucalyptus leaves that has perhaps the most scientific importance is that which is characteristic of the "Blood woods," viz., *E. corymbosa*, *E. intermedia*, *E. eximia*, *E. trachyphloia* and *E. terminalis;* of the "Swamp Mahoganies" *E. botryoides*

and *E. robusta;* of the "Blue Gum" *E. saligna*, of *E. tesselaris*, and a few others.

This particular venation is of importance because it is also generally characteristic of the Angophoras. The chemical evidence shows that the connection with the Angophoras is directly associated with those Eucalypts that have this particular venation in their leaves.

This venation, which is best seen in a photograph, appears to be indicative of a predominance of pinene in the oil, because this terpene is an important constituent in all those species that show this venation, while phellandrene is quite absent, and in the oil that we distilled from the leaves of *Angophora lanceolata*, pinene was also found, and proved by the formation of its nitrosochloride. This connection between the Angophoras and the Eucalypts is not the only chemical evidence that we can produce. A few years ago the Bureau of Agriculture for Western Australia sent to the Technological Museum a sample of the kino from the "Red Gum" *Eucalyptus calophylla*, and in the investigation of this kino a new substance was discovered, this was named "Aromadendrin." Its chemistry was undertaken by one of us and the results published in the Proceedings of this Society, August 5th, 1896.

In the year 1900 a new species of Angophora from the western portion of this State was described by one of us in the Proc. Linn. Soc., N.S.W. From the kino of this species *(A. melanoxylon)* a substance was obtained chemically identical with aromadendrin obtained from the kino of *E. calophylla.* A chemical connection was thus shown to exist between these two genera, at near this point, because eudesmin and not aromadendrin is generally the principal constituent of this character occurring in Eucalyptus kinos. When the additional chemical evidence respecting their oils had been obtained we referred to the venation of *E. calophylla*, and found it to correspond with that characteristic of the Angophoras.

We are not aware that the oil has yet been distilled from the leaves of *E. calophylla*, but from the chemical evidence and the

botanical characteristic of leaf venation it is very probable that when distilled, pinene will be found to be an important constituent of the oil and that phellandrene will be absent.

The venation of the leaves belonging to those species next in order is that which characterises the Eucalypts yielding eucalyptol oils. Although tending somewhat towards the venation of that group which give oils containing a predominance of pinene, yet the parallel transverse venation, like that of a feather, which is characteristic of the pinene group is not marked, and the venation and reticulation are exceeding delicate, the spaces between the principal veins are larger and a picture of the leaf has a much more graceful and delicate appearance. If we examine the photographs of the leaves of *E. Smithii*, of *E. globulus*, of *E. longifolia*, of *E. goniocalyx*, or of any other allied species which gives a first class eucalyptol oil, it will be seen that a great similarity of venation exists between them. The general appearance of the venation of these leaves, however, shows greater affinity to those species belonging to the pinene group than to those species having the venation characteristic of the phellandrene-peppermint group, and thus suggests a closer relationship to the pinene oil group.

It has long been known that pinene was a constant constituent in the oil of those Eucalypts rich in eucalyptol, and that phellandrene was generally quite absent. We think that the results we have obtained offer a very good explanation for the occurrence of pinene in these oils, and also suggest a reason for the varying amounts of that constituent in the oils of the various species belonging to this group.

All the oils obtained from those species whose leaves show this venation are characterised by the presence of pinene and of eucalyptol, the predominance or otherwise of the former influencing of course the amount of the latter. This group may very well be styled the eucalyptol-pinene group. The majority of the oils in this group do not contain phellandrene, but as the species branch off into the peppermint group, this constituent makes its appearance in increasing amount, but it is then seen that the principal

veins branching from the mid-rib become more acute or inclining towards the venation which characterises those species, the oils of which consist largely of the terpene phellandrene. But besides this portion which connects directly with the phellandrene-peppermint group there is a branching off from the eucalyptol pinene bearing species in another direction, the oils of which species all contain the aldehyde aromadendral and in which phellandrene is absent, this sub-group includes that portion of the mallees which embraces such species as *E. dumosa*, *E. polybractea*, *E. viridis*, *E. cneorifolia* etc., and which culminates in those species containing a maximum of aromadendral; these may be considered the typical "boxes" as *E. albens*, *E. hemiphloia* and *E. Woollsiana*. Those species belonging to the eucalyptol-pinene group which branch off into the phellandrene-peppermint group are continued through that group, the peppermint constituent increasing in amount in the oil of the various Eucalypts, until species like *E. dives* or *E. radiata* are reached. It will be observed from the photograph that in the venation of the leaves of these species, the lateral veins are more inclined to run parallel to the mid-rib and that the principal marginal vein is far removed from the outer edge of the leaf. Now, the marginal vein of the leaf of *E. melliodora* is somewhat far removed from the edge, and the value of this evidence is seen in the fact that we discovered phellandrene in the oil of this species long before the importance of the leaf venation in this connection had been demonstrated, and it appears probable that in this species we can detect the road through which the eucalyptol-pinene oils branch off into those consisting largely of phellandrene. This constituent is only present in small amount in this species at any time, and is often difficult to detect, but the solubility in alcohol of the oil, although rich in eucalyptol, indicates that we are probably dealing with an oil in which phellandrene may be present.

The next group of the Eucalypts which shows a well marked agreement between a characteristic venation of their leaves and the constituents of their oils is that which includes all those species

whose oils contain phellandrene and the ketone of peppermint taste and odour, and the presence of which constituent in the oil gives the name of "peppermints" to so many of our Eucalyptus trees. The principal terpene present in the oils obtained from species whose leaves have this venation is (with but one or two exceptions) phellandrene.

That it is possible to find species with this venation in which this terpene could not be detected is not to be wondered at, because the constituents found in Eucalyptus oils are present in varying proportions in the oils of the several species belonging to the several groups and pass over into the members of the other groups, and of course we find other species connecting the several groups together. It is thus that we find some oils rich in phellandrene and in which it is difficult to detect the peppermint constituent although it is not possible to decide with absolute certainty when a particular constituent is quite absent from any Eucalyptus oil.

It is, too, this closely related connection between numerous allied species, this gradation from one member to another, that makes the botanical study of the Eucalyptus so perplexing. The particular venation to which we are now referring is that which is seen in the leaves of *E. coriacea*, *E. Sieberiana*, *E. vitrea*, *E. dives*, *E. radiata*, *E. amygdalina*, *E. delegatensis*, *E. oreades* and many others. All the oils from these species contain phellandrene in varying amount, they all contain more or less of the peppermint ketone, while in some of them eucalyptol occurs, varying from traces in some species up to 20 or 30 per cent. in others. This group also contains the species (*E. piperita*) from which the first Eucalyptus oil was obtained. This was distilled by Dr. White in 1788, and owing to the presence of the peppermint constituent in the oil he gave the name of "Peppermint" to the tree, thus the first Eucalyptus species from this State received both its vernacular and specific names on account of the presence of a particular chemical constituent in its oil, what we have done in these researches is simply to amplify the earlier results of this chemical

TYPES OF EUCALYPTUS LEAF VENATIONS, WHICH INDICATE THE PRESENCE OF CERTAIN CHEMICAL CONSTITUENTS IN THE OIL.

evidence. We are now able to demonstrate most fully that of all the numerous peculiarities of the Eucalypts not one is of greater value in indicating differences in the several species or that is more conclusive in its results, than is the practical constancy of chemical constituents in identical species, a fact of the greatest scientific and economic importance.

It is thus possible to suggest in the majority of instances and with some degree of certainty, what the general constituents of an Eucalyptus oil will be, by the simple investigation of the venation of the leaves. By the reverse process, we ought to be able to form a very good idea of any species by the investigation of its products chemically. It has already been stated that a remarkable constancy is found in the chemical constituents of the oil of any particular species wherever grown, even if obtained from material collected from localities 300 or 400 miles apart. We have numerous instances of this constancy. Some time back we called attention to the fact that the oil obtained from a mallee (a shrubby form of Eucalypt) growing on the Blue Mountains at Lawson, Katoomba, etc., and known as *E. stricta* was different from that obtained from the supposed *E. stricta* growing around Berrima and Mittagong, but it was not possible to separate them on any known botanical characters, as no morphological differences could be detected, but the fact remained that the oils were different and always so, because to test this we obtained material from Berrima and Mittagong at different times of the year. The leaves of both species are thick and fleshy, so that the venation is externally quite indistinct, but if the leaves are boiled for some time in a dilute solution of potash and the cuticle on one side of the leaf then removed, it will be seen that *E. stricta* from Lawson has the venation characteristic of eucalyptol-pinene oils, inclining to the aromadendral group (eucalyptol being the principal constituent of this oil) while the leaves of the species from Berrima has the venation characteristic of *E. dives* and of the oils belonging to the phellandrene-peppermint group. The peppermint constituent has been found to be a constant constituent of the oil of this Eucalypt,

while eucalyptol is almost if not entirely absent. It may thus be assumed that organic differences are present and indicated by the venation of the leaves, and we conclude that like differences will be eventually detected in many other species of Eucalypts when the investigation shall have been carried more deeply by systematic research.

The oil of *E. stricta* contains a little aromadendral but no peppermint and it is one of the richest in eucalyptol that we have investigated. The matter thus becomes of technical importance, because if the two trees are not systematically separated, then the products would be different, and if worked, disappointment and perhaps loss would necessarily follow. We thus propose to make the Berrima form distinct, and to give it specific rank under the name of *Eucalyptus apiculata.*

In summarising the results there appears every reason to suppose that with the Eucalypts a gradual deviation from a type has taken place, and that the formation of characteristic constituents in these oils has been contemporaneous with the characteristic alteration or deviation of the venation of their leaves. That the constituents have been fixed and constant in the oils of the several Eucalypts for a very long period of time is demonstrated by the fact that whenever a species occurs over a large area of country the constituents of the oil are practically identical also, only differing in about the same amount as is to be expected with the oils from trees of the same species growing together in close proximity to each other. The venation of the leaves of individual species is comparatively similar throughout their geographical distribution, and their botanical characters show also a marked constancy. All this comparative constancy is probably accounted for by the long period of time that must have elapsed before a particular species could have established itself as such over so extensive a range as we find species to-day.

The chemical and botanical peculiarities must also have been fixed primarily, because we do not find the differences in characters

one might expect by environment. Our researches seem to show that the species are only well marked varieties in which the distinctive characters have become permanent. The well defined chemical groups branching off from a centre, which groups in their several members show gradations in which the chain is in places somewhat complete, demonstrates, we think, most strongly the insignificant part that hybridism could have played in the formation of the several species of Eucalyptus.

We would like to express our thanks to Mr. M. F. Connelly of this Museum, who by his perseverance, has overcome the difficulty of producing the nature photographs of the leaves, and to Messrs. Rumsey and Tremain of the Technical College for the preparation of the excellent lantern slides.

Explanation of Plate.

Fig. 1.—Leaf of *Eucalyptus corymbosa*, Sm.—This venation is indicative of the presence of pinene in the oil. Note the close parallel lateral veins, the thick mid-rib, and the position of the marginal vein close to the edge of the leaf. The yield of oil from leaves showing this venation is small, there not being room between the lateral veins for the formation of many oil glands.

Fig. 2.—Leaf of *Eucalyptus Smithii*, R. T. B.—This venation is characteristic of species whose oil consists principally of eucalyptol and pinene. Note the more acute lateral veins which are wider apart, thus giving more room for the formation of oil glands; the yield of oil is thus larger in these species. The marginal vein is further removed from the edge and is slightly bending to meet the lateral veins.

Fig. 3.—Leaf of *Eucalyptus radiata*, Sieb.—This venation is characteristic of those species whose oil consists largely of phellandrene and the peppermint ketone. Note the still more acute and fewer lateral veins. The marginal vein has also become so far removed from the edge that a second one occurs, and the slight bending as seen in Fig. 2, has culminated in this group in a series of loops. The spaces for the formation of oil glands are also practically unrestricted and a large yield of oil is thus obtainable.

NOTE ON THE SESQUITERPENE OF EUCALYPTUS OILS.

By HENRY G. SMITH, F.C.S., Assistant Curator,
Technological Museum.

[*Read before the Royal Society of N. S. Wales, November 6, 1901.*]

WHEN an Eucalyptus oil is quantitatively determined for eucalyptol with phosphoric acid a pink or reddish colour is usually given to the mixture. This is particularly the case with the oils of higher specific gravity which consist largely of eucalyptol. The appearance of this reddish colour has often been taken to denote the end reaction for this determination, but the constituent causing it cannot be considered as an indicator for eucalyptol because the greater the proportion of the constituent occurring in a particular oil the sooner the colour will appear.

The constituent of Eucalyptus oils causing this colour reaction with phosphoric acid is a sesquiterpene, and it probably occurs in varying amount in all the oils of the series. In some of these it occurs in great abundance, and over fifty per cent. of the oil of *E. hæmastoma* distilled above 225° C., nor, was this an abnormal sample, because material of this species was obtained from localities nearly one hundred and fifty miles apart, and both the samples of oil were in agreement, indicating that the sesquiterpene follows the general rule with these oils, of identical species of Eucalypts giving practically identical oils irrespective of location. The oils from the following species were also found to contain the sesquiterpene in quantity:—*E. eximia*, *E. nova-anglica*, *E. trachyphloia*, *E. affinis*, *E. maculata*, *E. crebra*, *E. viminalis*, and *E. acmenoides*. It may occur in these oils with either pinene or phellandrene as the principal terpene, and eucalyptol may be either present or absent. There appears to be only one sesquiterpene in Eucalyptus oils, because the product obtained by fractional distillation (finally over sodium) from the mixed higher

boiling portions of several of the oils was practically identical with that obtained from the oil of *E. hæmastoma* in the same manner. Crystallised chemical compounds do not appear easy to produce from it, and attempts to form a crystallised dihydrochloride, a nitrosochloride, or a nitrosite, were unsuccessful, nor did it appear possible to form a solid sesquiterpene alcohol from it. Having thus to rely upon the product obtained by repeated fractional distillation, finally over sodium, it cannot be considered to be sufficiently pure to determine its constants, with certainty, although the results obtained were fairly satisfactory.

The specific gravity of the sesquiterpene from the mixed oils was 0·9229 at 19° C., and of that from *E. hæmastoma* at the same temperature 0·9249. When it shall have been obtained pure it will most probably be found to be inactive to light. It boiled under atmospheric pressure at 260 – 265° C.

An analysis resulted as follows:—0·1366 gram gave 0·4388 gram CO_2 and 0·1502 H_2O, equal to 87·6 per cent. carbon and 12·2 per cent. hydrogen. $C_{15}H_{24}$ requires 88·23 per cent. C. and 11·77 per cent. H.

A vapour density determination, using the vapour of diphenylamine, gave 11·8 cc. of moist air at 19° C. and 754 mm. pressure from 0·1027 gram, indicating a molecular weight of 214. $C_{15}H_{24}$ equals 204.

The most characteristic test of this sesquiterpene is the very fine colour reactions it gives with acids and with bromine. If one or two drops of the sesquiterpene be mixed with 2 or 3 cc. of glacial acetic acid and the vapour of bromine allowed to pass down the tube, immediately it reaches the liquid a crimson colour is formed rapidly passing downwards, if agitated the whole becomes crimson at once, soon changing to violet and in about five or ten minutes it has become of a deep indigo-blue colour, which remains persistent for a long time. A few drops of hydrobromic acid gives the same colour reactions as with bromine, and as a bromide is formed from the sesquiterpene with the evolution

of hydrobromic acid, it is probably to the formation first of this acid that the colour given with bromine is due. Hydrochloric acid gives the same colours, but the reaction is slower.

In a solution prepared as above, sulphuric acid gives a crimson colour at once, soon changing to a purplish colour. Phosphoric acid in the same manner gives first a pink then a crimson and finally a violet colour. These colour reactions are exceedingly delicate.

The evidence so far obtained show this sesquiterpene to have been previously undetermined. It is proposed to give it the name *Aromadendrene* utilising Dr. Andrews' name for the genus.

I am indebted to my colleague, Mr. R. T. Baker, F.L.S., for the botanical determination of the species which provided the material.

THE THURRAWAL LANGUAGE.

By R. H. MATHEWS, L.S., Corres. Memb. Anthrop. Soc., Washington, U.S.A.

[*Read before the Royal Society of N. S. Wales, November 6, 1901.*]

THE Thurrawal speaking people were formerly spread over the south-east coast of New South Wales from Port Hacking to Jervis Bay, and extended inland for a considerable distance. For some years past I have studied the Thurrawal tongue, and now submit the grammatical outlines of its structure. Considerations of space render it necessary to touch only upon the fundamental elements of the language.

I have discovered that many of the nouns, adjectives, prepositions and adverbs—in addition to the verbs and pronouns—are inflected for number and person. This fact has not hitherto been reported, to my knowledge, in any part of Australia, although to some extent observed in certain islands of the Pacific Ocean.

In verbs, pronouns, and other parts of speech subject to conjugation and inflection, there is a double form of the first person of the dual and plural, which has also been observed in Polynesia, and among the Amarinds of North America. Two forms of the dual were noticed by Rev. L. E. Threlkeld among the aborigines of Lake Macquarie, New South Wales, but he says this did not extend to the plural.[1]

This paper claims to enlarge, in some degree, the circle of Australian ethnology. Exhibiting the general structure of any native tongue must be valuable to philologists, in enabling them to compare our aboriginal languages with each other, and also with those of the people of Polynesia and the East Indian Archipelago, whence the primitive inhabitants of this Continent are

[1] An Australian Language (Sydney), pp. 17 and 91.

supposed by several writers to have come—an opinion which has also been promulgated by myself.[1]

In the tables of declensions and conjugations I have given the root words and their suffixes in full, believing that this course will place the whole matter more clearly before the reader than by giving the suffixes separately. I agree with Mr. Sidney H. Ray, when he says, "The practice of writing the modifying particles apart from the root in many languages tends to obscure the fact of inflection, and makes the particle appear as a separate word."

A short vocabulary of the leading nouns, verbs, adjectives and other parts of speech in the Thurrawal language, is now in preparation, and will be completed as soon as the pressure of other duties permit.

It may be as well to mention that Rev. Wm. Ridley refers[2] to a language called Turuwul, which he says was spoken at Port Jackson and Botany Bay, of which he published a brief list of words. A short vocabulary is also given by him of the "Language spoken at George's River, Campbelltown and Appin." He likewise gives a brief vocabulary of what he calls the Wodi-Wodi language. Mr. Ridley does not, however, give any rules of the grammatical structure of the dialects under notice.

Vocabularies of the language spoken by the aborigines in the neighbourhood of Sydney are given by Mr. D. Collins[3] and by Capt. John Hunter.[4] A perusal of my vocabulary at the end of this article will show that many of the words reported by Mr. Collins and by Capt. Hunter, respectively, more than a century ago are still in use, and recognisable, among the Dharruk natives.

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[1] Proc. Amer. Philos. Soc., Phila., Vol. xxxix., pp. 556 - 578. (Map).

[2] Kamilaroi and Other Australian Languages, (Sydney, 1875), pp. 99 - 114.

[3] Account of the English Colony in New South Wales, (London, 1798), pp. 610 - 615.

[4] Historical Journal of Discovery in New South Wales, (London, 1793), pp. 407 - 411.

Mr. E. M. Curr[1] gives abridgements of the vocabularies of Hunter, Collins and Ridley.

ORTHOGRAPHY.

Nineteen letters of the English alphabet are sounded, comprising fourteen consonants and five vowels, namely, *a*, *b*, *d*, *e*, *g*, *h*, *i*, *j*, *k*, *l*, *m*, *n*, *o*, *p*, *r*, *t*, *u*, *w*, and *y*. The system of orthoepy adopted is that of the circular issued by the Royal Geographical Society, London.

It is frequently difficult to distinguish between the short sound of *a* and that of *u*. A thick sound of *i* is occasionally met with, which closely approaches the short sound of *u* or *a*. *G* is hard in all cases. *R* has a rough trilled sound, as in hurrah!

Ng at the beginning of a word, as *ngu* in *ngu'ra*, a camp, has a peculiar sound, which can be got very closely by putting *u* before it, as *ungu'* and articulating it quickly like one syllable. At the end of a syllable it has substantially the sound of *ng* in the word sing. *W* always commences a syllable or word, and has its ordinary consonant sound in all cases.

The sound of the Spanish *ñ* is frequent, both at the beginning or end of a syllable. *Y*, followed by a vowel, is attached to several consonants, as *dya*, *lyi*, *tyu*, &c., and is pronounced in one syllable, the initial sound of the *d*, *l*, *t*, or as the case may require, being retained. *Y* at the beginning of a word or syllable has its ordinary consonant value.

Dh is pronounced nearly as *th* in "that," with a slight sound of *d* preceding it. *Nh* has nearly the sound of *th* in "that," with an initial sound of the *n*. The final *h* is gutteral, resembling *ch* in the German word *joch*.

T is interchangeable with *d*; *p* with *b*; and *g* with *k* in most words where these letters are employed. An approach to the sound of *j* is frequently given by the natives, which may be rendered by *dy* or *ty*—thus, *dya* or *tya* has very nearly the same

[1] The Australian Race, (Melbourne 1886) Vol. III. pp. 410 - 419.

sound as *ja*. At the end of a syllable or word, *dy* or *ty* is sounded as one letter; thus, in *bir-rity*, sick, the last syllable can be pronounced exactly by adding *e* to the *y*, making it *rit-ye*. Then commence articulating the word, including the *y*, but stopping short without sounding the final, or added *e*. *Dy* at the end of a syllable can be pronounced in the same way, the sound of *d* being substituted for that of *t*. In all cases where there is a double consonant, each letter is distinctly enunciated.

Articles.

There are no articles corresponding to our "a" or "the" in any Australian tongue with which I am acquainted.

Nouns.

Number—Nouns have three numbers, the singular, dual, and plural. There are euphonic variations and elisions in the suffixes, according to the termination of the word used :

(*a*)	Singular	An eaglehawk,	mulyan
	Dual	A couple of eaglehawks,	mulyanbulali
	Plural	Several eaglehawks,	mulyanbuloala
(*b*)	Singular	A bandicoot,	mundu
	Dual	A couple of bandicoots,	mundulali
	Plural	Several bandicoots,	munduloala

Gender—Words for "male" and "female" denote the gender of animals in most cases: Guraura kaualgang, a male opossum; guraura nunganung, a female opossum.[1] The male of birds is bianhung, as jaula bianhung, a cock pheasant, and jaula nunganung a hen. Different words are used to distinguish sex in the human family, as, yuiñ, a man ; mega or ngurrungal, a woman ; bunbari, a boy ; yirrauiang, a girl.

Case.—The principal cases are the nominative, possessive and objective, the latter including the accusative, dative and ablative forms.

1. There is a double form of the nominative case. When it is only necessary to name the object under attention, as yuiñ, a

[1] These words are inflected for number, as stated in dealing with the adjectives.

man—or when an intransitive verb is used, as yuiñ ngulli, the man sits—the noun is unchanged. But when the noun is connected with a transitive verb, it takes a suffix, as yuiñ-dyu bulmaia, the man struck; moreover, the form of this suffix varies according to the termination of the noun, or the vowel sounds contained in it. This has been designated the nominative agent, and will be understood from the following examples:—In the simple nominative we have juggarnañ, a boy; mirrigang, a dog; ngurrungal, a woman; bunbari, a youth; wuragal, a young man who has been initiated. When the subject is performing some act, certain suffixes are employed, as, juggarnañdya dhuñ manda, the boy a fish caught. Mirrigangga guraura bubbugaia, a dog an opossum bit. Ngurrungalla mundha gulanya, a woman a snake killed. Bunbari-i gunungwir yurinya, the youth a porcupine hit. Wuragalgangga bundaia, the man chopped.

It will be observed that the agent suffix in the above examples has euphonic changes according to the sound of the word it is attached to; thus, it is dyu after the u in yuiñ; dya after juggarnañ; ga following the gang in mirrigang, la after the gal in ngurrungal; and i following the final i in bunbari.

2. The possessive case takes a suffix to the name of the thing possessed, as well as to that of the possessor:—Yuiñguli nguranhung, a man's ngura or camp. Bunbariwuli warranganhung, a boy's boomerang. Mirriganguli wurranyung, a dog's puppy. Mirriganguli wurranhumbuloala, a dog's puppies (several). Megawuli gujaganhung, a woman's child. Megawuli gujagangulanhung, a woman's children (several). Megawulal gujagangulandhunnung, the children of several women. Gujagawulingubbamurranhung, a child's mother. Yuiñbulaliwuli warranganbulanhung, a boomerang belonging to two men.

The name of every object in the universe over which any kind of ownership exists, can be conjugated by means of possessive suffixes for person and number:—

Singular	1st Person	My head,	Wollardyen
	2nd „	Thy head,	Wollarngun
	3rd „	His head,	Wollarnhung

Dual	1st Person	Our heads, incl.	Wollarngullung
		Our heads, excl.	Wollarngullin
	2nd „		Your heads,	Wollarawulung
	3rd „		Their heads,	Wollarwulanu
Plural	1st Person	Our heads, incl.	Wollarnyinnung
		Our heads, excl.	Wollarnyinnin
	2nd „		Your heads,	Wollarnhurung
	3rd „		Their heads,	Wollardhunnang

A boomerang, warrangan, can be inflected in the same way. An example in the singular will be sufficient:

Singular	1st Person	My boomerang,	Warrangandyen
	2nd „	Thy boomerang,	Warranganngun
	3rd „	His boomerang,	Warranganhung

In these examples the pronominal suffix follows the noun, the words reading, head my, boomerang my, and so on. In the dual and plural, first person, there are two forms of the word—one marked "incl.," including the person spoken to; and the other, "excl.," in which the person addressed is excluded. If a couple, or several, articles are claimed, an infix is inserted between the noun root and the possessive termination, as follows:—

Warranganbulalidyen, boomerangs two mine
Warranganbuloaladyen, boomerangs several mine.

3. The accusative is the same as the simple nominative in direct statements such as—Yuiñdyu gujaga bulmaia, the man the child struck. There are exceptions to this rule, however, when an instrument is the direct object of the verb, as, Warrangandya wawarnang yerriangai, a boomerang at a crow threw I. Here the accusive, "boomerang," takes a similar suffix to the nominative. Again, Ngurrungalla ngadyungo ngaimilai, the woman water brings; and Wuragalgangga mundubangga bundaia, the man with a tomahawk chopped.

Again, in expressions where the instrument is the remote object, the accusative is unchanged, and the suffix is added to the instrumental case, thus, Yuiñdyu warrangandya gujaga bulmaia, the man with a boomerang a child struck. In such instances the nominative suffix is often omitted, and the instrumental only employed.

4. Examples of the dative case are: Juggarnañ Bunnabiu dhundya ngaimaia, the boy Bunnabi to fish carried. Ngurawulaliu yendingulling, camps two to go we (dual excl.) or, we two go to different camps. Warrangan babamurrawulingun, a boomerang to thy father belongs. Mundubang yuiñgunhung, a tomahawk for the man. Babamurrungun nyilli binding, to thy father this give.

Frequently the dative case is contained in the verb, as, manmadhan, caught for me; bindadhan, gave to me. In other instances the dative is expressed in the pronoun, as Ngaiagangunhung, for me. (See Pronouns).

5. The following are a few specimens of the ablative case:—Ngurrungalla buddaiin nadyungo ngaimilai, the woman from the hole water carries. Jaulaidhangu ngurain, he runs from the camp. Yuiñdyu Bunnabi-in dhundya ngaimilai, a man from Bunnabi fish carries. Yuiñ nyilli warrangandya gungalendin jindama, man this a boomerang from myrtle makes.—Gungalen is the myrtle tree.

The ablative is sometimes expressed by a form of the verb, as, bundaiadhan, took from me. The sense of the ablative is often obtained by means of the accusative case, thus, instead of saying, "The man was bitten by a snake," a native says, a snake bit the man. The ablative can also be indicated by a pronoun, as, Ngaiagandin, from me; ngaiagandi, with me.

The following are a few miscellaneous examples in different cases, which are placed together because they are all of one character:—Gujagadyen, child my. Babandyang, father my. Gujagangunandyen, for my child. Babanduggunhung, for my father. Gujagandidyen, with my child. Babandindidyen, with my father.

ADJECTIVES.

Adjectives follow the nouns they qualify, and take the same inflexions for number and case:

A large squirrel,	Bunggu gaian (squirrel large)
A couple of large squirrels,	Bunggulali gaianbulali
Several large squirrels,	Bungguloala gaianbuloala.

Gaianburnung is a stronger way of expressing "large," and has the dual and plural suffixes as before. Sometimes burnung is used by itself, as yuiñ burnung, a man large. A man of unusual stature is spoken of as yuiñ burndal, a man very large.

Equality is expressed by Gulagang nhai—gulagang nham, short this—short that; or Bundauariwulali, long both. Inferiority by Gurnung nhai—nuggung nham, bad this—good that. There is a sort of superlative, Gulagangang, very small; gumbuludhung, very strong.

Words used to distinguish the sex of animals are treated as adjectives, and inflected for number, as follows:

A kangaroo, male,	Buru kaualgang
A couple of male kangaroos,	Burulali kaualgangbulali
Several male kangaroos,	Buruloala kaualgangbuloala

When used predicatively, as, you are stupid, adjectives can be conjugated the same as an intransitive verb. Nuggung, means good, and also well in health.

Present.

Singular	1st Person	I am good,	Nuggungai
	2nd „	Thou art good,	Nuggumbi
	3rd „	He is good,	Nuggung
Dual	1st Person	We are good, incl.	Nuggungul
		We are good, excl.	Nuggungulling
	2nd „	Ye are good,	Nuggumbul
	3rd „	They are good,	Nuggumbula
Plural	1st Person	We are good, incl.	Nuggunyang
		We are good, excl.	Nuggunyilling
	2nd „	Ye are good,	Nuggunhur
	3rd „	They are good,	Nuggumba

Past.

Singular	1st Person	I was good,	Nuggungabambeh
	2nd „	Thou wast good,	Nuggumbibambeh
	3rd „	He was good,	Nuggungbambeh

Future.

Singular	1st Person	I will be good,	Nuggungabambeng
	2nd „	Thou wilt be good,	Nuggumbibambeng
	3rd „	He will be good,	Nuggumbambeng

Another form of the future is as follows:—

Singular	1st Person	I will be good,	Nuggungabambinaiungai
	2nd „	Thou wilt be good,	Nuggungabambinaiiñ
	3rd „	He will be good,	Nuggungabambinaiang

It is thought unnecessary to give the duals and plurals of the three last examples, which are formed in a similar way.

Imperative Mood—Present Tense.

Singular	1st Person	Be thou good,	Nuggungung
Dual	2nd „	Be ye good,	Nuggungumbul
Plural	2nd „	Be ye good,	Nuggungunhur

Future Tense.

Singular	3rd Person	Let him be good,	Nuggungwianda
Dual	3rd „	Let them be good,	Nuggungwiumbulaia
Plural	3rd „	Let them be good,	Nuggungwiunhaia

Conditional Mood—Present Tense.

Singular	1st Person	I may be good,	Nuggungamurra
	2nd „	Thou mayst be good,	Nuggumbimurra
	3rd „	He may be good,	Nuggumurra

Past Tense.

Sing.	1st Per.	Perhaps I was good,	Nuggungamurra-bambeh
	2nd „	Perhaps thou wast good,	Nuggumbimurra-bambeh
	3rd „	Perhaps he was good,	Nuggumurra-bambeh

It will be seen that in these two examples the words are the same as in the present and past tenses respectively of the indicative mood, with the addition of murra. The reader can easily prepare a table showing the duals and plurals for himself. Dyua could be used instead of murra. The negative is expressed by placing the word ngambana before the adjective, as, Ngambana nuggungai, not good am I.

The following is a set of suffixes which are often used with adjectives and some intransitive verbs when referring to personal qualities or attributes. They appear to add the meaning of "really," or "quite," as, Nuggung-gaiingai, good I really am, or I am quite well. Gumbul-gaiingul, we (dual incl.) are quite strong. Nungaiangai, I slept very well, and so on. The attached table contains the suffixes only.

		Present.	Past.
Singular	1st Person	-gaiingai	-gaiangai
	2nd ,,	-gaiiñ	-gaiabi
	3rd ,,	-gaii	-gaia
Dual	1st Person	-gaiingul, incl.	-gaiangul, incl.
		-gaiingulling, excl.	-gaiangulling, excl.
	2nd ,,	-gaiimbul	-gaiauul
	3rd ,,	-gaiimbula	-gaiauula
Plural	1st Person	gaiinyang, incl.	-gaianyang, incl.
		-gaiinyilling, excl.	-gaianyilling, excl.
	2nd ,,	-gaiinhur	-gaianhur
	3rd ,,	-gaiinha	-gaiaua

		Future.
Singular	1st Person	-gaiinaiangai
	2nd ,,	-gaiinaiañ
	3rd ,,	-gaiinaiang
Dual	1st Person	-gaiinaiangul, incl.
		-gaiinaiangulling, excl.
	2nd ,,	-gaiinaiambul
	3rd ,,	-gaiinaiambula
Plural	1st Person	-gaiinaianyang, incl.
		-gaiinaianyilling, excl.
	2nd ,,	-gaiinaianhur
	3rd ,,	-gaiinaianha

There is another set of suffixes, which qualify the word they are attached to. Nuggung-wingai, conveys the meaning, "I am fairly well, or getting better."

		Present.	Past.
Singular	1st Person	-wingai	-wiangai
	2nd ,,	-wiñ	-wiabi
	3rd ,,	-wi	-wia
Dual	1st Person	-wingul, incl.	-wiangul, incl.
		-wingulling, excl.	-wiangulling, excl.
	2nd ,,	-wimbul	-wiauul
	3rd ,,	-wimbula	-wiauula
Plural	1st Person	-winyang, incl.	-wianyang, incl.
		-winyilling, excl.	-wianyilling, excl.
	2nd ,,	-winhur	-wianhur
	3rd ,,	-winha	-wiaua

Future.

Singular	1st Person	-wunaiungai	
	2nd „	-wunaiañ	
	3rd „	-wunaiang	
Dual	1st Person	-wunaiangul, incl.	
		-wunaiangulling, excl.	
	2nd „	-wunaiambul	
	3rd „	-wunaiambula	
Plural	1st Person	-wunaianyang, incl.	
		-wunaianyilling, excl.	
	2nd „	-wunaianhur	
	3rd „	-wunaianha	

PRONOUNS.

Pronouns follow the verb or adjective which they qualify, and are inflected for number and person. They comprise the nominative, possessive and objective cases, a few examples in each of which will be given.

The following table exhibits the personal pronouns—the nominative being given in one column, and the nominative-agent in another, on the same line to the right.

Singular	1st Person	I	Ngaiagang	Ngaiagangga
	2nd „	Thou	Nyindigang	Nyindigangga
	3rd „	He	Namarang	Nyilligadangga
Dual	1st Person	We, incl.	Ngulgang	Ngulgangga
		We, excl.	Ngunngulling	Ngunngullingga
	2nd „	Ye	Bilgang	Bilgangga
	3rd „	They	Nawulali	Nyilliwulali
Plural	1st Person	We, incl.	Nyulgang	Nyulgangga
		We, excl.	Nyunulling	Nyunullingga
	2nd „	Ye	Nyirgang	Nyirgangga
	3rd „	They	Nawandalwali	Nyillalla

An emphatic or reflexive variety of pronouns are as under:

Singular	1st Person	Myself	Ngaiagamirrang
	2nd „	Thyself	Nyindigamirrang
	3rd „	Himself	Namirrang
Dual	1st Person	Ourselves, inclusive	Ngulgamirrang
		Ourselves, exclusive	Ngungullamirrang
	2nd „	Yourselves	Bilgamirrang
	3rd „	Themselves	Namirrambulali

Plural	1st Person	Ourselves, inclusive	Nyulgamirrang
		Ourselves, exclusive	Nyunullimirrang
	2nd „	Yourselves	Nyirgamirrang
	3rd „	Themselves	Nowandalmirrang

Relative Pronouns.—I have not observed any relative pronouns—who, which, etc.—but their signification is obtained by such expressions as the following: Yuiñ wurriin yengulaia—guggaiiri, the man far walked—he is hungry (the man walked a long way which makes him hungry). Yuiñ dhalluga yendadha—warrangandya gurrangamadadhan, the man yesterday went [away]—a boomerang stole he from me, that is, the man who went away yesterday stole my boomerang.

Indefinite Pronouns.—Middhungal, another. Middhungalwulali a couple of others. Middhungalwilligang, several others. Middhungalmirriung, some others. Mirruandalwali, no one.

The possessive pronouns, where only one object is referred to, are as under:—

Singular	1st Person	Mine	Ngaiawooli
	2nd „	Thine	Nyinduwuli
	3rd „	His	Indiwuli
Dual	1st Person	Ours, inclusive	Ngulganguli
		Ours, exclusive	Ngunngullinguli
	2nd „	Yours	Bilganguli
	3rd „	Theirs	Indiwulaliwuli
Plural	1st Person	Ours, inclusive	Nyulganguli
		Ours, exclusive	Nyunullinguli
	2nd „	Yours	Nyirganguli
	3rd „	Theirs	Indalwuli

There are modifications of these possessives where two or more articles are spoken of; thus, if a native desire to convey that a couple of boomerangs, for example, are his property, he can say, Ngaiawuliwulali. If he claim several, he says, Ngaiawulal; and so on through all the persons and numbers. In other words, the pronoun takes the same inflection for number as the noun to which it refers. Another way of expressing ownership of two or more objects, is to annex the dual or plural suffix to the name of the thing possessed, as, Warranganbulali ngaiawuli, or, Warran-

ganbuloala ngaiawuli; that is, boomerangs-two mine, or, boomerangs-several mine, and so on. The reader is also referred to an earlier page for the possessive suffixes to nouns, as, warrangandyen, my boomerang.

The pronouns, "for me," etc., in the dative case, are as follows:

Singular	1st Person	For me	Ngaiaganguntbung
	2nd "	For thee	Nyindiganguntbung
	3rd "	For him	Indiwunthung
Dual	1st Person	For us, incl.	Ngulganguntbung
		For us, excl.	Ngunngullinguntbung
	2nd "	For ye	Bilganguntbung
	3rd "	For them	Indiwulaliwunthung
Plural	1st Person	For us, incl.	Nyulganguntbung
		For us, excl.	Nyunullinguntbung
	2nd "	For ye	Nyirganguntbung
	3rd "	For them	Indalwunthung

In the ablative case there are the following inflexions in the pronoun signifying "from me," etc.

Singular	1st Person	From me	Ngaiagandin
	2nd "	From thee	Nyindigandin
	3rd "	From him	Namarandin
Dual	1st Person	From us, inclusive	Ngulgandin
		From us, exclusive	Ngunngullingdin
	2nd "	From ye	Bilgandin
	3rd "	From thou	Nawulalin
Plural	1st Person	From us, inclusive	Nyulgandin
		From us, exclusive	Nyunullindin
	2nd "	For ye	Nyirgandin
	3rd "	For them	Nawandalwalin

There is another form, meaning "with me," etc.

Singular	1st Person	With me	Ngaiagandi
	2nd "	With thee	Nyindigandi
	3rd "	With him	Namarandi

and so on through the dual and plural.

Demonstratives.—These are very numerous, and are inflected for number, case and tense. They usually follow the word qualified. We will commence with the nominative:—

Singular.	Dual.	Plural.
Nhai, this	Nhaiwulali	Nhaial
Nham, that	Nhawulali	Nhawulal
Narria, yon	Narriawulali	Narrial

These three terms have each several variations according to the relative position of the object referred to in regard to the speaker.

Nom. Agent—If the individual represented by the pronoun is doing some act, nyilli is used, as nyilli bulmandhan, this (fellow) strikes me. The dual is nyilliwulali, and plural nyillal. Nyilla, instead of nyillee, is used in the singular in the past and future tenses. If the person referred to is in the rear of the speaker, nyillundyimung is used; if he is in front, nyillundya. There are also several other modifications of the word to convey different shades of meaning.

Possessive.—The possessive case takes the following suffixes, for which one example will be sufficient :

Singular,	Nhawuli, belonging to that (fellow).
Dual	Nhawulaliwuli, belonging to those two.
Plural	Nhalwuli, belonging to those all.
Dative	Nhaialwunung, for all these (plural).
Ablative	Nhaialdeen, from all these (plural).

Tense is shown in the following examples :—Present—Yuiñ nyinyi, the man is here ; Yuiñ nhameng, the man is there. Past —Yuiñ nyinyawaia, the man was here; Yuiñ nhawaia, the man was there. Future—Yuiñ nyinyawawang, the man will be here; Yuiñ nhawawang, the man will be there. Nyiniwuli, belonging to here (this place). Yawali, that one also. Yawalingai, I also. Nyilligarangga, that fellow also (did it). Ngai, to here; ngundyin, from here. Mungandin, from this place.

Interrogatives.—The interrogative, Ngunnung nyinyim? "who there?" varies with the number of persons referred to:—Singular, ngunnung ; dual, ngunnumbulali ; plural ngunnumbuloala.

If "who" refer to an act described in a transitive verb, it becomes ngunnungga, and changes with the number of persons

acted upon in the objective case:—singular, Ngunnungga nham, who him (struck, threw at, etc.); dual, Ngunnunggawulung nawulali, who those, etc.; plural, Ngunnunggadhünnung nawulaliwuli, who those, etc.

It also varies in the nominative case if the performers be one or more:—singular, Ngunnungga, who (struck, threw at, etc.); dual, Ngunnunggawul who two (struck, threw at, etc.); plural, Ngunnungganhur, who several (struck, threw at, etc.).

There is a possessive form in each number:—singular, Ngunnunguli, whose is this? dual, Ngunnunguliwulali, whose are these (two)? plural, Ngunnungulal, whose are these (several)?

The word can also be conjugated for number and person. An example in the singular will be sufficient:

Singular { Ngunnungadhan, who me (struck, spoke to, etc.)
Ngunnunganyin, who thee (struck, spoke to, ect.)
Ngunnunga, who him (struck, spoke to, etc.)

Ngunnungamurra, who might it be? Dative, Ngunnunggunhung, who for? Ablative, Ngunnundin, who from. Ngunnung warrangandhurra, who has the boomerang? Ngunnunganyin gaia, who thee told? Nominative, Mingang, what is that? Minganggа, what did that? Possessive, Minganguli, what belonging to. Dative, Mingangunhung, what for? Mingarang, how many? Mingang bumbadi, what wantest thou? Winggala, which one? Waianha nuggung, which is good?

This word can also be conjugated:—Mingangudyen, what for me (struck thou); Mingangubi, what for him (struck thou); Mingangudbungalin, what for us two (struck thou); Mingangudbenyinnin, what for us several (struck thou); and so on.

Verbs.

Verbs have three numbers, three persons in each number, and three tenses. The moods are the indicative, imperative, and conditional. The verb stem and a pronominal suffix are embodied in one word, which is inflected for number and person. This is done with each of the tenses, as in the following conjugation of the verb, "to strike or beat."

Active Voice—Indicative Mood.

Present Tense.

Singular	1st Person	I strike	Bulmaingai
	2nd „	Thou strikest	Bulmaiñ
	3rd „	He strikes	Bulmai
Dual	1st Person	We strike, inclusive	Bulmaingul
		We strike, exclusive	Bulmaingulling
	2nd „	Ye strike	Bulmainbool
	3rd „	They strike	Bulmainboola
Plural	1st Person	We strike, inclusive	Bulmainyang
		We strike, exclusive	Bulmainyilling
	2nd „	Ye strike	Bulmainhoor
	3rd „	They strike	Bulmainha

Past Tense.

Singular	1st Person	I struck	Bulmaiangai
	2nd „	Thou struckest	Bulmaiabbi
	3rd „	He struck	Bulmaia
Dual	1st Person	We struck, inclusive	Bulmaiangul
		We struck, exclusive	Bulmaiangulling
	2nd „	Ye struck	Bulmaiaual
	3rd „	They struck	Bulmaiauala
Plural	1st Person	We struck, inclusive	Bulmaianyang
		We struck, exclusive	Bulmaianyilling
	2nd „	Ye struck	Bulmaianhoor
	3rd „	They struck	Bulmaiaua

If two or more persons were struck, we could say:—Bulmaiangumbula, I struck two; Bulmaiangandhunnang, I struck several.

Future Tense.

Singular	1st Person	I will strike	Bulmangai
	2nd „	Thou wilt strike	Bulmañ
	3rd „	He will strike	Bulmang
Dual	1st Person	We will strike, incl.	Bulmangul
		We will strike, excl.	Bulmangulling
	2nd „	Ye will strike	Bulmanbul
	3rd „	They will strike	Bulmanbula
Plural	1st Person	We will strike, incl.	Bulmanyang
		We will strike, excl.	Bulmanyilling
	2nd „	Ye will strike	Bulmanhur
	3rd „	They will strike	Bulmanha

If the intention were to beat more than one, we could say:—Bulmangambulaia, I will beat those two; Bulmangandhunnang, I will beat all those.

Imperative Mood—Present Tense.

Singular	2nd Person	Strike thou	Bulmara
Dual	2nd „	Strike ye	Bulmaraual
Plural	2nd „	Strike ye	Bulmaranhur

The negative form of this tense is as follows:—

Singular	Strike thou not,	Bulmambin
Dual	Strike you not,	Bulmambimbul
Plural	Strike you not,	Bulmambinhur

Future Tense.

Singular	3rd Person	Let him strike	Bulmaianda
Dual	3rd „	Let them strike	Bulmambulai
Plural	3rd „	Let them strike	Bulmanhaia

Another form of the verb is:—

Let me strike him, Bulmurrungandha
Let us two strike him, Bulmulngul
Let us all strike him, Bulmulnyang

Conditional Mood—Present Tense.

Singular	1st Person	I may strike	Bulmaingamurra
	2nd „	Thou mayest strike	Bulmaingmurra
	3rd „	He may strike	Bulmaimurra

Past Tense.

Singular	1st Person	I may have struck	Bulmaiangamurra
	2nd „	Thou mayest have struck,	Bulmaiabbimurra
	3rd „	He may have struck	Bulmaiamurra

The last two examples are the same as the present and past tenses respectively of the indicative mood, with the addition of murra, The dual and plural numbers are formed in the same manner. Dyua is also used as a suffix, instead of murra, in all the above examples.

Passive Voice.

Transitive verbs have no passive voice, but its place is supplied by changing the sentence from the passive to the active form,—

the object in the passive becoming the subject in the active voice. The meaning of the sentence: a fish was caught by the woman, is rendered: the woman caught a fish—ngurrunggalla dhuñ mandha.

Middle Voice—Indicative Mood.

Present Tense.

Singular	1st Person	I beat myself,	Bulmaiilingai
Dual	1st „	We, incl., beat ourselves,	Bulmaiilingulling
Plural	1st „	We, incl., beat ourselves,	Bulmaiilinyang

Past Tense.

Sing.	1st Per.	I have beaten myself	Bulmaiilyangai
Dual	1st „	We, incl., have beaten ourselves,	Bulmaiilyangul
Plural	1st „	We, incl., have beaten ourselves,	Bulmaiilyanyang

Future Tense.

Sing.	1st Per.	I will beat myself	Bulmaiilungai
Dual	1st „	We, incl., will beat ourselves,	Bulmaiilungul
Plural	1st „	We, incl., will beat ourselves,	Bulmaiilunyang

There are forms of the verb for the other persons, but it is thought the foregoing are sufficient to illustrate the rules.

Imperative Mood.

Singular	Beat thyself	Bulmaiiling
Dual	Beat yourselves,	Bulmaiilingbul
Plural	Beat yourselves,	Bulmaiilinhur

The negative is, Strike not thyself, Bulmaiilingbịng.

Reciprocal.—There is a reciprocal form of the verb which is of course restricted to the dual and plural, as follows:—

We two, incl., beat each other,	Bulmullangul
We all, incl., beat each other,	Bulmullanyang
You two beat each other,	Bulmullumbul
You all beat each other	Bulmullanhur
They two beat each other,	Bulmullainbula
They all beat each other,	Bulmullainha

Modifications of the verb to convey different shades of meaning are very numerous, as will be apparent from the following few

examples, which are in the past tense, the present and future being omitted.

Singular	1st Person	He struck me,	Bulmaiadhan
	2nd "	He struck thee	Bulmaianying
	3rd "	He struck him	Bulmaianyilla
Dual	1st Person	He struck us, incl.	Bulmaiangullung
		He struck us, excl.	Bulmaiangulleen
	2nd "	He struck ye	Bulmaiaualung
	3rd "	He struck them	Bulmaiaulung
Plural	1st Person	He struck us, incl.	Bulmaianyannung
		He struck us, excl.	Bulmaianyannin
	2nd "	He struck ye	Bulmaianthurung
	3rd "	He struck them	Bulmaiadhunnung

When the striking is done by two persons, the pronominal suffix is varied :

Singular	1st Person	They two struck me,	Bulmaiaulaian
	2nd "	They two struck thee,	Bulmaiaulanying
	3rd "	They two struck him,	Bulmaiaula

When several persons join in doing the beating another variation in the verb takes place :

Singular	1st Person	They all struck me,	Bulmaiauaian
	2nd "	They all struck thee,	Bulmaiauanying
	3rd "	They all struck him,	Bulmaiaua

The two last examples can also be conjugated for dual and plural.

When two or more are the recipients of the beating, the form is as follows, one example only being given in each number :

Singular	I struck two	Bulmaiangambula
Dual	We, inclusive, struck two,	Bulmillangul
Plural	We, inclusive, struck several,	Bulmillanyilling

The dative case is thus indicated by the verbal suffix:—

Singular	2nd Person	I gave to thee,	Bindaguñ
	3rd "	I gave to them,	Bindyangai
Dual	2nd Person	I gave to ye,	Bindyangambulung
	3rd "	I gave to them,	Bindyangambula
Plural	2nd Person	I gave to ye,	Bindyanganthurung
	3rd "	I gave to them,	Bindyangandhunnung
Singular	1st Person	He gave to me,	Bindadhan
	2nd "	He gave to thee,	Bindanying
	3rd "	He gave to him,	Bindaia

and so on through the dual and plural numbers. Bindich bingalin, do not give to us.

Other verbs contain an ablative meaning:

Singular	2nd Person	I took from thee,	Bundaiaguñ
	3rd „	I took from him,	Bundaiangai
Dual	2nd Person	I took from ye,	Bundaiangambulung
	3rd „	I took from them,	Bundaiangambula
Plural	2nd Person	I took from ye,	Bundaianganthurung
	3rd „	I took from them,	Bundaiangandhunnung
Singular	1st Person	He took from me,	Bundaiadhan
	2nd „	He took from thee,	Bundaianying
	3rd „	He took from him,	Bundaia

the conjugation being continued for the dual and plural.

The verb takes an inflection for the same number as the object noun in the following phrases:

A squirrel saw I,	Bunggu nandangai
A pair of squirrels saw I,	Bunggulali nandangambula
Several squirrels saw I,	Bungguloala nandangandhunnung

The number of the verb agrees with the nominative in such expressions as, We (dual inclusive) saw a squirrel, Bunggu nandangul; we (plural inclusive) saw a squirrel, Bunggu nandanyang.

Verbs are also modified to express a negative meaning:

Strike not thou me	Bulmumbindyen
Strike not us (dual exclusive)	Bulmumbinbungullin
Strike not us (plural exclusive)	Bulmumbinbenyunnin
Come not thou to me	Yendabindyen
Come not you (dual) to me	Yendabinbuldyen
Come not you (plural) to me,	Yendabinhurdyen
Go not thou away	Yenbin
Go not you (dual) away	Yenbimbul
Go not you (plural) away	Yenbinhur

Another negative form is as follows:

I struck not	Bulmullanganangai
Thou struckest not,	Bulmullanganabi
He struck not,	Bulmullangana,

and this inflection continues through the dual and plural.

Prepositions.

Expressions containing the equivalents of our prepositions are sometimes independent words, but consist chiefly of the incorporation of verbs or pronouns with nouns and adjectives, which give a prepositional meaning. This can be better illustrated by a few short sentences:

Burumbadindhan, it is facing, or in front of me. Bulgadyanda, at my back. Nguraidyen, at my camp. Nunganandyi, round this way. Nunganandyimung, around (behind me). Narrimung, over yonder.

Gundulali burrumunbula, two trees between; that is, between two trees.

Warrungalwundu dhurragangga, on the other side of the creek; Nowundubulla dhurragangga, on this side of the creek. Bullawundu, more this way.

Mudyeri warrungaldin bungaiilaiangai, the canoe from the other side I paddled, or, I paddled across in the canoe.

Nunganandyi wurrijanthung gundu, around at the farther side of the tree.

Mudjewuru nhari dharratbaiangai, brush yonder through went I, or, I went through yonder brush (dense scrub).

Buru ntha bullawarri-mirriri ngullai, kangaroo that on the hill-top sits. Bullawarriu dhullibaingai, the hill up go I. Bullawarriin wurwaingai, the hill down go I. Bullawarree warrungalee wowīngī, the hill along the side of go I, or, I am going along the side of the hill.

Nunganandyi burrima yalwaingai, around the ironbark tree go I. Gundu ñilli bowañingai, tree this up I climb, or, I am climbing up this tree. Yarrawangga narri irribaingai, cave that I go into.

The names of the points of the compass are: gurru, north; kwia, south; bulu, east; wugga, west. Gurruwundu is northerly from any specified spot; kwiawundu is southerly; buluwundu is easterly; and wuggawundu westerly. There are also names for

the intermediate points. Frequently a native will state the location of anything by its compass direction from a known tree or other determinate point.

Some prepositions can be conjugated for number and person, as in the following example:

Singular	1st Person	Behind me	Yellungadyen
	2nd „	Behind thee	Yellungangun
	3rd „	Behind him	Yellunganthung
Dual	1st Person	Behind us inclusive	Yellungangulling
		Behind us exclusive	Yellungangalin
	2nd „	Behind ye	Yellungawulung
	3rd „	Behind them	Yellungawulanhu
Plural	1st Person	Behind us inclusive	Yellunganyunnung
		Behind us exclusive	Yellunganyunnin
	2nd „	Behind ye	Yellunganhurung
	3rd „	Behind them	Yellungadhunnung

Adverbs.

Like the prepositions, adverbs consist of separate words as well as being expressed by means of verbs which are modified in their terminations so as to convey an adverbial meaning.

Of time.—Dyedyungalla, a month or moon. Dyedyungbulali, two months or moons. Dyedyung, the moon. Nyillamung, now. Burrenhung, soon. Burriwalganga, some time. Dhalluga, yesterday. Dhadyilam or dhallugawal, day before yesterday. Nhauwai, to-day. Dhadyawarri, long ago. Dhadyam, by and bye. Burriwurri, this forenoon. Burriu, to-morrow. Burrinhung, day after to-morrow. Dhurrandhurung, always.

Affirmation and negation.—Ngai, yes; ngargudhung, certain; ngaiang or mirra, no; murrungai, none I have; mirruguyung, nothing; ngamurra, perhaps.

Interrogation.—Illing, how? Illingjaiabi, how didst thou do it? This word can be inflected for number and person: Illingbi mandha, how didst thou catch (a fish, etc.?) Illingbul mandha, how did you two catch (a fish, etc.?) Illinhur mandha, how did you several catch (a fish, etc.)? Yununggubi yenda, when didst

thou go? Yunnunggu yenbang, when will he go? Waddha, where? Waddhawia, where is he? Waddhainbi mandha, where didst thou catch it? Waddhana ngura, where is the camp? Waddhian baulaiabi, whence camest thou?

This word can also be inflected for person and number:

Singular	1st Person	Waddhungai,	where am I?
	2nd „	Waddhubi	where art thou?
	3rd „	Waddhu	where is he?

and so on through the dual and plural.

Another form of the word is as under:

Singular	1st Person	Wagungai,	where go I?
	2nd „	Wagubi,	where goest thou?
	3rd „	Wagu	where goes he?

Yet another form is "Which way shall I go?

Singular	1st Person	Waddhawauwangai, which way shall I go?
	2nd „	Waddhawauwaiñ, which way shalt thou go?
	3rd „	Waddhawai, which way shall he go?

Another form still is as follows:

Singular	1st Person	Waddhawaiangai, where have I been?
	2nd „	Waddhawaiabi, where hast thou been?
	3rd „	Waddhawaia, where has he been?

These examples can all be conjugated for the dual and plural.

Of number: Middhunga, once. Bullaru, twice. Mingarang, how many times?

Of order: Mirramirrang, first. Burru, between or in the midst. Nguddhunbulali, one on each side. Yellungali, last. Nyadyerri, back.

Of quantity: Burramurrung, much or plenty. Mirragangang, a little. Nauwallung, enough. Burramurrandhurrabi—mirraguyungai, thou hast plenty—I have none. Mirraguyumbi—burrumurrundhurrangai, thou hast nothing—I have plenty. Mirragang yundingai, some left I have, or, I have a little left. Burramurrung yundingai, plenty I have left. Yukun, like.

Quality: Janboi, slowly. Gurnumbungai, badly. Nuggumbungai, well. Idhanyi, quickly.

Adverbs are compared in a similar way to that used in the comparison of adjectives:—Yuiñ nhai jimbai—ngurrunggal nhai jimbowuddhumbai, man this thirsty—woman this very thirsty, or, the woman is more thirsty than the man. Bunbari nhai jauaierra, ma yuiñ nhai irrandaia. Boy this very swift, because man this he overtook, or, this boy is faster than the man, because he overtook him.

CONJUNCTIONS.

There are very few conjunctions in the language. We often find an erratic syllable, ba, with its euphonic variants ma, ya, etc., interposed between two words to prevent hiatus, and which also serves at times as a conjunction equivalent to "and" or "because."

INTERJECTIONS AND EXCLAMATIONS.

The use of these is limited. Gwak! is equivalent to "look out." Ngatkaiang means "take care." Yukkai is an exclamation of surprise. Ngang ngang is about equivalent to "is that so." Yai! is calling attention. Ngaiaruiñ! you fellows! Ngaiung, calling to one person. Any vocative can be inflected for number, according as one, a pair, or several, are called.

NUMERALS.

Middhung, one; bullar, two. The ordinals are, Middhunga, once; bullaru, twice. Wawulli, a few.

After the fourth line on page 134, add the following:—

The adjective takes the agent or possessive suffix belonging to the qualified noun; thus: Bunggu gaiandyu guraura gulanya, a squirrel large an opossum killed. Yuiñburnungguli mirriganhung, the big man's dog.

The dative and ablative cases are expressed in a similar manner, by their respective suffixes to the adjective. These remarks apply, *mutatis mutandis*, to the adjectives in the Gundungurra and Dharruk languages.

APPENDIX.

The Gundungurra Language.

The Gundungurra tribes occupied the country to the west of the Thurrawal and Dharruk, as far as Goulburn, where they adjoined the Ngunawal tribes. An abstract of the grammar of the language is now supplied, to show its affinity to the Thurrawal, being the result of my own investigations among the Gundungurra blacks.

Nouns.—The dual and plural of nouns are shown by suffixal particles: Singular, Wille, an opossum. Dual, Willewulali, a pair of opossums. Plural, Willedyargang, several opossums.

In the human family different words are used for the masculine and feminine, as, Murrin, a man; bullan, a woman. Bubal, a boy; mullangan, a girl. Another name for a man is, baual.

Among animals gender is distinguished by placing gaual or gumbañ after the name of the male, and dhuruk after that of the female, thus: Gula gumbañ, a buck bear; gula dhuruk, a female bear. Gumbañ and dhuruk take the same inflection for number as the noun with which they are used.

This language has the same cases as the Thurrawal, some only of which will be exemplified: There are two forms of the nominative case, one merely naming the object at rest, as, Murrin ngamburamañ, the man sleeps. When the man is doing some act, a suffix is applied, as, Murrindya gula wobburañ, the man a bear struck. The example last given also serves to show the accusative, because in that expression no change takes place in the word gula. In some phrases, however, there is an inflection, as, Berraga yerrimangga, I am throwing a boomerang; Bubal ñin berraga yellimunnin, boy this a boomerang will carry. Again, Bauala berra bubalngura yerririñ, a man a boomerang at a boy threw. In this example the remote object, bubal, the boy, takes a suffix.

In the possessive case the name of the possessor and that of the object possessed each take a suffix: Bubalngu ngauangung, a boy's mother. Baualngu berrawung, a man's boomerang. Mirrigangu

gudhawung, a bitch's puppy. In the possessive case, and in the nominative too, the suffixed particle varies with the termination of, and the vowel sounds contained in, the word to which it is attached. Moreover, these suffixes are applied to the simple nominative form of the noun, not the agent nominative.

The name of any object over which possession can be exercised by a native is subject to inflection for number and person by means of possessive suffixes: Berradya, my boomerang (berra). Berranyi, thy boomerang. Berrung, his boomerang; and so on through the dual and plural. In the dative case they say, Ngurane yerrabi, to the camp go thou. The ablative form is, Ngurajea yerrabi, from the camp go thou.

Adjectives.—Adjectives are declined for the dual and plural, and are placed after the nouns they qualify:—Wirria buggarabang, an iguana large; Wirriawulali buggarabangbulali, a pair of iguanas large; Wirriadyargang buggarabandyargang, several iguanas large.

Comparison is effected in a manner similar to that employed in the Thurrawal; and certain adjectives, when used as predicates, can be conjugated like intransitive verbs, the same as in that language.

Pronouns.—Pronouns have person, number, and case, but are without gender. Some of the nominative and possessive pronouns are as under:—

Sing.	I	Gulangga	Mine	Gulangguya
	Thou	Gulanjee	Thine	Gulangunyi
	He, she	Dhanuladhu	His, her	Dhanulangu
Dual	We, incl.	Gulanga	Ours, incl.	Gulangalung
	We, excl.	Gulangalung	Ours excl.	Gulangalangun
	You	Gulambu	Yours	Gulambulung
	They	Dhanudyula	Theirs	Dhanudyulangu
Plural	We, incl.	Gulambanyan	Ours, incl.	Gulanyanung
	We, excl.	Gulambanyilla	Ours, excl.	Gulanyanungun
	You	Gulambanhu	Yours	Gulanhurung
	They	Dhanujimalang	Theirs	Dhanujimalangu

The following are examples in the ablative case:—

Singular	With me	Gulanguria	From me	Gulangarajia
	With thee	Gulangurunyi	From thee	Gulangaranyi
	With him	Dhanulangura	From him	Dhanulangaraji

Emphatic personal pronouns are:

Singular	1st Person	Myself	Mittimbaldya
	2nd „	Thyself	Mittimbalnyi
	3rd „	Himself	Mittimbalgung

The three last examples can be continued through the dual and plural.

Some of the interrogatives are:—Nominative—Unnaga, who? Unnagawula, who (two)? Unnagamulan, who (several)? Possessive —Unnagangu, whose (is this)? Ablative—Unnagangureji, who from? The word can be inflected for number and person:— Unnagajiba, who art thou? Unnagaiau, who are you (two)? Unnagamillanhu, who are those (several)? Nominative—Minya, what? Minyamanja, what's the matter? Dative—Minyanniba, what for? Ablative—Minyangura, what with?

The following are a few of the demonstratives:—Nominative— Nyin, this; Dhanu, that; Nidyula, those two. Possessive— Nyingulangul, belonging to this; Dhanugulangu, belonging to that; Waranalangu, belonging to you; Nidyulangu, belonging to those two. Ablative—Nyingulangura, with this; Nguna, here; Ngununggula, belonging to here.

There are no well defined relative pronouns—the sense of the relative being obtained as already illustrated in the Thurrawal.

Verbs.—Verbs have the same numbers, persons, tenses and moods as those of the Thurrawal language, and although the suffixed particles differ, they are dealt with in a similar manner, as represented in the following table of the conjugation of the verb "to sit."

The verbal terminations vary to show that the act has only just been done, that it happened some little time ago, that there was a continuance in its performance, and so on. If a native say, "I threw (a boomerang, for example), he may use any of the following forms of the verb, according to what he wishes to express: Yerrimuingga, yerribalimuingga, yerriringga, yerribaliringga, etc., all meaning "I threw."

Indicative Mood.

		Present, I sit, etc.	Past, I sat, etc.	Future, I will sit, etc.
Sing.	1st Per.	Ngullamanya	Ngullamuringga	Ngullamuningga
	2nd „	Ngullamanji	Ngullamurinji	Ngullamuninji
	3rd „	Ngullamañ	Ngullamuriñ	Ngullamunin

		Present, We sit, etc.	Past, We sat, etc.
Dual	1st Per.	Ngullamanga, incl.	Ngullamuringa, incl.
		Ngullamangalung, excl.	Ngullamuringalung, excl.
	2nd „	Ngullamanbu	Ngullamurinbu
	3rd „	Ngullamanbula	Ngullamurinbula

		Future, We will sit, etc.
Dual	1st Person	Ngullamuninga, inclusive.
		Ngullamuningalung, excl.
	2nd „	Ngullamuninbu
	3rd „	Ngnllamuninbula

		Present, We sit, etc.	Past, We sat, etc.
Plural	1st Per.	Ngullamanyan, incl.	Ngullamurinyan, incl.
		Ngullamanyilla, excl.	Ngullamurinyilla, excl.
	2nd „	Ngullamanhu	Ngullamurarinhu
	3rd „	Ngullamandyulung	Ngullamurindyulung

		Future, We will sit, etc.
Plural	1st Person	Ngullamuninyan, inclusive
		Ngullamuninyilla, exclusive
	2nd „	Ngullamuninhu
	3rd „	Ngullamunindyulung

The negative is formed by infixing the word muga between the verb stem and the suffix, thus:—

Singular	Ngullamugamanya,	I sit not;
	Ngullamugamanji,	Thou sittest not;
	Ngullamugamañ	He or she sits not;

and so on through all the persons, numbers, and tenses.

Imperative Mood—Present Tense.

Singular,	2nd Person	Sit thou,	Ngullai
Dual	„	Sit you,	Ngullaiul
Plural	„	Sit you,	Ngullaianhur

The conditional mood, and also the middle and passive voices are omitted, being similar in structure to those of the Thurrawal. The numerous modifications of verbs to convey different shades of meaning are also analogous to those of the language mentioned.

Prepositions.—As in the Thurrawal dialect, prepositions may be either separate words, or consist of modifications of verbs to give them a prepositional meaning. Several prepositions can be inflected for number and person, thus:—

Singular	Willingaia, behind me (in the rear) Willinganyi, behind thee Willingawung, behind him.

Adverbs.—These consist of independent words and modifications of adjectives and verbs. A few interrogatives are: Wanjan, how? Wannambalang, how many? Ngundani, where art thou? Ngundaba where is it? Some adverbs can be inflected, as follows:

Singular	Ngundinia, Ngundininyi, Ngundiniung,	where go I where goest thou where goes he

The dual and plural numbers are omitted in this and the preceding example for want of space.

Conjunctions and *interjections* have their places in the language.

Numerals.—Meddung, one; Bulla, two; Irran, a large number.

THE DHARRUK LANGUAGE.

The Dharruk speaking people adjoined the Thurrawal on the north, extending along the coast to the Hawkesbury River, and inland to what are now Windsor, Penrith, Campbelltown, and intervening towns. A cursory outline of the Dharruk grammar, together with a short vobabulary of some of the most important words in general use, may be of some value to comparative philology. This grammar and vocabulary have been compiled by me from the lips of old natives acquainted with the language.

Nouns.—Number—Nouns have the singular, dual, and plural numbers:—Wirriga, an iguana; Wirrigabula, a couple of iguanas; Wirrigadyarralang, several iguanas.

Gender.—Dhullai, a man; Dyin, a woman; Wungar, a boy; Durungaling, a girl. The gender of animals is denoted by an additional word, kaual for the male, and wiring for the female, as Walaru kaual, a buck wallaroo; Walaru wiring, a doe wallaroo.

Case.—The nominative case has two forms, one of which simply names the person or thing, as Wungar, a boy. The other form represents the subject, or the instrument, in action, *e.g.*, Wungara bumarangga kerraiba, the boy a boomerang threw. Here the name of the boy and that of the instrument each take a suffix. Again, when the instrument is in the accusative case, a suffix is employed, as, Boomerangga kerraibadya, a boomerang threw I. Moreover, these suffixes fluctuate according to the termination of the word to which they are attached.

The possessive case has two suffixes, like the Thurrawal, as, Dyingu kurungbi, a woman's child (kurung). Any article over which possession can be asserted is subject to inflection for number and person by means of suffixes, analogously to the Thurrawal and Gundungurra, examples of which are not considered necessary.

Adjectives.—An adjective takes the same inflection as the qualified noun, and follows it:—Ngunuñ kaual, a flying-fox, male; Ngununbula kaualbula, a couple of male flying-foxes; Ngunundyarralang kaualdyarralang, several male flying-foxes. The suffix is often omitted in one of the words, the last one generally taking the inflection.

The comparison of adjectives, and their conjugation like intransitive verbs in certain cases, is analogous to the Thurrawal.

Pronouns.—The following are some of the nominative pronouns in the singular—the dual and plural being passed over for want of space, in this and undermentioned examples. The simple nominative is given in the first column, and the nominative-agent in the second.

Singular	1st Person	Ngaia	Ngaiadya
	2nd „	Nyindi	Nyindidya
	3rd „	Nanu	Nanudya

Examples of the possessive pronouns are as under:

Singular	1st Person	Mine	Jannunggai
	2nd „	Thine	Nyinnunggai
	3rd „	His	Nannunggai

Dative—Jannawigu, for me, and so on. Ablative—Jannawi, with me, and so on.

The following are some interrogative pronouns:—Nominative, Nyan, who? Nyanda, who (did it)? Possessive, Nyannungai, whose is this? Dative, Nyangu, who for? Nominative, Ming, what? Dative, Minganguñ, what for.

Verbs.—The verb has three numbers, with the usual persons, tenses and moods. There are also two forms in the first person of the dual and plural to express the inclusion or exclusion of the individual addressed. As the manner of conjugating these verbs is substantially the same as in the Thurrawal, exigencies of space compel me to omit them.

Adverbs.—Yelluñ, how? Wattungga, where? Wilguja, whither? Kabu, by and bye; Yuin, yes; Beal, no; Murraga, perhaps; Burrapur, to-morrow.

Prepositions, Conjunctions and *Interjections.*—Space will not admit of examples of these.

Numerals.—One, wagulwai; two, buler; three, buriwai; four, wagulwurri, apparently a derivation from "one-three."

Every part of speech which can be inflected for person and number in the Thurrawal language can be treated in a similar manner in the Dharruk.

Vocabulary of Dharruk Words.

The Family.

A man, dhulli
An old man, kaianyung
Husband, mullaming
Clever man, kuraji
Child, kurung
Small boy, wungar
Boy carried in bag (on mother's back), wungara juguma
A woman, dyin
Old woman, wiring
Wife, dyinmang
Girl, durungaling
Father, bianya
Mother, waianya
Decrepit old person, harabundi

The Human Body.

Head, kobbara
Forehead, ngurran
Hair of head, gittan
Beard, yarring
Eye, mibberai
Nose, nuga
Neck, kungga
Ear, kuri
Mouth, mundu
Lips, willin
Teeth, Yira
Breast (female), ngubbung
Navel, mumbirri
Belly, bindhi
Rump, kurpa

Anus, bungading
Flank, binning
Back, buyu
Penis, winji
Erection, wathuk
Testicles, karau
Vulva, mùndura
Hair on pudendæ, nguruguri
Urine, yillabil
Excrement, kuni
Sexual desire, kuthaling
Copulation, nguttatha
Masturbation, ganmillutthi
Venereal, midjung
Arm, nurung
Hand, dhummar
Thigh, dhurra
Knee, kuruk
Foot, dunna
Paunch, kurrema
Blood, mula
Fat, kurai
Bone, jara

Inanimate Natural Objects.

Sun, kuñ
Moon, jillak
Stars, kimperwali
Orion's Belt, dhungagil
Pleiades, dhinburri
Sunshine, bunnal
Thunder, murungal
Lightning, jerraral
Rain, muruku
Dew, gillabiñ
Fog, kurpuñ
Frost, dalara
Hail, kuruwillang
Fresh water, bado
The ground, dubbar
Mud, milluñ
A stone, kiber
Sand, marang
Light, killi
Darkness, minnek
Heat, yuroka
Coldness, duggara
Camp, ngurra
Fire, kwiang
Hut, gunji
Smoke, kudjal
Food, ngunnuñ
Day, burriang
Night, minnek
Morning, burpigal
Evening, waragal
A splinter, dhuraga
Hill, bulga
Grass, durawai
Bark shed by gum and other trees, kurrung-durrung
Hole in a tree, kumir
Leaves of trees, jirang
Bird's nest, ngurra
Eggs, kubbin
Honey, kudyung
Edible grub, burradhun
Pathway, muru
Shadow of a tree, bulu
Tail of animal, dun

Mammals.

Native bear, kulamañ
Dog, mirri
Opossum, wali
Kangaroo-rat, kanaming
Native-cat (black and white) bulungga
Native-cat (black and yellow), muraging
Rock wallaby, wollabi
Flying-fox, ngunuñ
Bandicoot, burraga
Flying squirrel, bangu
Sugar squirrel, chubbi
Ringtail opossum, bukari
Kangaroo, buru
Wallaroo, bitthang or wolara

Birds.

Birds collectively, bujan
Crow, wagun
Laughing jackass, kukundi
Curlew, warebun

Quail, moumbi
Eaglehawk, burumurring
Emu, mariang
Common magpie, karuk
Black magpie, wibbung
Black duck, yurungai
Mopoke, binnit
Night owl, budhawa
Bronze wing pigeon, kutging
Lark, murrajulbi
Rosella parrot, bunduluk
Blue Mountain parrot, warin
Greenleek parrot, kuma
Parrakeet, jirrang
Common hawk, kutthawai
King-fisher, jirramba
Pee-wee, birrerik
Plover, burranjarung
Crane, durali
White cockatoo, kirrawe

Fishes.

Perch, wuggara
Sprat, kumbara
Eel, burra
Gudgeon, duru
Turtle, kutukulung
Muscle, juggung

Reptiles.

Iguana, wirriga
Water lizard, bidjiwong
Sleepy lizard, muggadung
Small lizard, bunburra
Black snake, jirrabity
Frog, kung-gung
Brown snake, murragauan

Insects.

Large locust, bulla
Small locust, jirrabirrin
Blow fly, marang
Louse, bundyu
Nit of louse, jagara
Jumper ant, juljul
Bull-dog ant (red), kut-mut
Bull-dog ant (black), wuggajin
Centipede, jingring
Mosquito, dyura
Scorpion, dundi
Green-head ant, kunuma

Trees and Plants.

Any leaning tree, bulbi
Any dead tree, kwibul
Any hollow tree, birreko
Ti-tree, (soft bark), budjor
Ti-tree (prickly), bunya
Apple-tree, bunda
Stringybark, buran
Wattle, wattungulle
Ironbark (broad leaf), dirrabari
„ (narrow leaf), muggargru
Cherry tree, kwigan
Gum-tree, yarra
Jeebung, mambara
Corkwood, kulgargru
Bullrushes, baraba
Yam, midiñ

Weapons, etc.

Tomahawk, mogo
Koolamin, kungun
Yamstick, kunni
Spear, of wood, kummai
Spear, reed, wari
Spear-thrower, womra
Spear-shield, hilamong
Waddy-shield, millathunth
Club with knob, kuburra
Club, plain, bundi
Boomerang, bumarañ
Net bag, juguma

Adjectives.

Alive, muthung
Dead, baletti
Large, mari
Small, ngurrang
Tall or long, kurare
Low or short, munal
Good, ngubaty
Bad, kuraji
Thirsty, durral
Red, jarri
White, burrakutti

Black, butu
Full, buruck
Quick, baro
Slow, wurral
Blind, muffming
Deaf, kumbarobalong
Strong, bulbwul
Valiant, muttong
Afraid, jerrun
Right, budyer
Wrong, kuraji
Tired, wunal
Blunt, as an edge, mundhagud
Fat, kurai
Lean, jarra jarra
Cold, tuggara
Angry, kular
Sleepy, nungga
Glad, mujar
Sorry, ngandu
Greedy, jirra
Grey-headed, warunggat
Sick, budjil
Stinking, kuja
Bald-headed, ngurranbulba [lit. forehead bare]
Pregnant, bindhiwurra
Hollow, as a tree, etc., birreko

Verbs.

Die, boi
Eat, patama
Drink, wittama
Sleep, nungare
Stand, dharage
Sit, ngulluwa
Talk, paialla
Tell, goanyi
Walk, yanna
Run, wumerra
Bring, yalingeñ
Take, maniau
Make, bunggawurra
Break, kidjikbane
Strike, dutbara
Wound, baiwurra
Arise, boraga
Fall down, bululbali
Observe, nea
Hear, ngarra
Give, nguyangun
Love, ngubaty
Sing, burria
Weep, dunga
Cook, as food, kunnama
Steal, karama
Request, kullea
Blow, with breath, bumbi
Climb, kalua
Conceal, dutba
Jump, karuka
Laugh, jandiga
Scratch, jirranga
Forget, bulala
Stare at, mutbi
Send, yenna
Shine, killi
Suck, wittama ngubbung, lit., to drink from the breast
Swim, waringa
Search for, pittuma
Spit, juki
Smell, kunda
Throw, kurraibi
Roast, kunnama
Whistle, woinga
Pretend, wangit
Kiss, bonge
Vomit, muli
Dance, dungara
Dive, mulbari
Sting, windhurrame

THE GUMS, RESINS AND OTHER VEGETABLE EXUDATIONS OF AUSTRALIA.

By J. H. MAIDEN, Government Botanist and Director of the Botanic Gardens, Sydney.

[*Read before the Royal Society of N. S. Wales, December 4, 1901.*]

BOTH for the Technological Museum and for the Botanic Gardens Museum, I have been a collector of Australian vegetable exudation for twenty years. These products are valuable for diagnostic botanical purposes apart from their economic uses. The vast majority of our exudations are mere museum curiosities at present, and some of these which are readily obtainable in large quantities, *e g. Eucalyptus* and *Angophora* kino, Grass-tree gum, Australian Sandarac, have not obtained that footing in the world's commerce that it was expected they deserved. There is no doubt, however, that these exudations will for many years provide interesting material for research, and as many of them doubtless do not contain new bodies or are of complex constitution, they may attract the attention of the young man who is feeling his way towards scientific research. Some of them of course require a sound knowledge of organic chemistry and the appliances of a modern laboratory.

A botanical classification has been adopted for these exudations; at the present time it will be found most useful, and allied Natural Orders being in justaposition it will be seen to what extent allied Orders yield allied exudations. When the exudations are more comprehensively examined it will be found a simple matter to arrange them in regard to their chemical composition, which will be a very interesting and practical classification, since the user is, as a rule, not much concerned with the origin of his material, so long as it is uniform in composition, properties and appearance.

The classification of the exudations from some of the species is only intended to be provisional. In the absence of some of the products which I have had no opportunity of examining, I am unable to say, for instance, whether some of them should be grouped as "gums," or as "gum-resins."

The list of exudations is fairly long, and some of the papers in the bibliography give reference to species not separately enumerated. Nevertheless it will be observed that our knowledge of Australian vegetable exudations is only superficial, and if residents in the country will systematically collect all exudations (accompanied by flowering or fruiting twigs or other botanical evidence), we shall soon be in a position to present further work on this interesting group of substances. A drawback to the collection arises from the fact that the exudation of many of the gums etc. is erratic and accidental, and in our sparsely populated country the gums are often washed away by rain, and the resins often disappear by fire and removal by bees etc., and so escape the attention of the collector.

From the time of Governor Phillip our vegetable exudations have been fitfully sent to Europe, but as a general rule they were sent home as curiosities, were not collected in sufficient quantity for chemical examination, and no botanical data nor information as to locality and quantity available accompanied the specimens. Following is an instance in point:—"I sent to England specimens of five different gums, in order that they might be examined. These consist of an elastic gum, closely resembling India-rubber; gum tragacanth; another gum yielded by a sort of *Capparis (Adansonia)* and which I believe to be hitherto unknown; and two kinds of gum-resin."[1]

Many Natural Orders yield both gums and resins (or gum-resins). The following are what may be termed gum-yielding Orders, but they exceptionally yield resins:—Pittosporeæ *(Pittosporum)*; Rutaceæ; Meliaceæ *(Cedrela* etc.); Sapindaceæ *(Dodonæa)*;

[1] Journ. of Two Exped., Grey, p. 275.

Leguminosæ *(Acacia, Galactia)*; Araliaceæ *(Astrotriche)*; Proteaceæ *(Grevillea* etc.); to which may be added Myrtaceæ, the kino-yielding Order par-excellence, but which also contains *Syncarpia*, a resin-yielding genus.

The following may be termed resin-yielding Orders, but they exceptionally yield gums :—Euphorbiaceæ *(Aleurites)*; Liliaceæ *(Xanthorrhœa)*; Coniferæ *(Araucaria)*.

The matter of production of gums, resins, and perhaps kinos in the same Order is of great interest to the physiological botanist in the first place and well worthy of investigation.

As regards kinos, the Natural Order Myrtaceæ is by far the most important, but the following Australian Orders also yield them, and accurate observation will greatly increase the list :—Malvaceæ, *(Adansonia, Bombax)*; Leguminosæ, *(Lonchocarpus, Mezoneuron, Milletia)*; Saxifrageæ, *(Ceratopetalum, Schizomeria)*; Rhizophoreæ, *(Rhizophora)*; Myrtaceæ, *(Eucalyptus, Angophora)*; Euphorbiaceæ, *(Baloghia)*; Casuarineæ, *(Casuarina)*.

The following yield useful soluble gums in fair abundance :—Meliaceæ, *(Flindersia maculosa)*; Sapindaceæ, *(Atalaya hemiglauca)*; Leguminosæ, *(Acacia*, chiefly the dry country species, and Australia is no exception to the general rule which holds that arid countries produce the best soluble gums).

The following additional genera are most scientifically and economically important as regards their latex, gums and resins, and it would be a tempting field for a post-graduate course if the University could see its way to reward its students for research in regard to such of the exudations as have not been thoroughly worked out :—Burseraceæ, *(Canarium Muelleri)*; Myrtaceæ, *(Eucalyptus, Angophora, Syncarpia)*; Sapotaceæ, *(Sideroxylon)*; Proteaceæ, *(Grevillea robusta)*; Urticeæ, *(Ficus)*; Liliaceæ, *(Xanthorrhœa)*; Coniferæ, *(Agathis, Araucaria; Callitris)*.

Certain gums and resins *(e.g., Leschenaultia, Triodia)* are laboriously collected and used by the aborigines; it would be desirable to endeavour to procure them in quantity.

I have taken cognizance of some genera from India and other parts of the world represented in Australia, but which although producing exudations in their native country have not yet been found to yield them in Australia. The line of enquiry is suggestive and if followed up may lead to the discovery of exudations that have hitherto been passed over. As regards those exudations I have included from Polynesia, I have included them for the reason which weighed with me in regard to the Indian genera; I also was guided by a feeling that as these islands are practically adjacent to Australia, it would be a convenient arrangement to include them in any general account of the vegetable exudations of that continent.

CAPPARIDEÆ.

Capparis nobilis, F.v.M., "Wild Lemon."

The gum consists almost wholly of Pararabin and resembles those of the Sterculiaceæ. See Maiden and Smith (63)[1]

PITTOSPOREÆ.

The genus *Pittosporum* is one which yields both gums and resins. See Maiden (56).

Pittosporum phillyrœoides, DC., (Syn. *P. acacioides*, A. Cunn.), "Native Willow," etc.

"Several Acaciæ useful . . . for their gum; but the latter is even excelled in clearness and solubility by that obtained from *Pittosporum acacioides*." (Mueller, *First General Report*, 1853, p. 6.)

Pittosporum undulatum, Vent. Our common native Pittosporum.

For an investigation of this gum-resin see Maiden (56). Dr. Lauterer (33) has also examined a soft resin from this tree.

Pittosporum rhombifolium, A. Cunn.

Yields a gum-resin apparently similar to the preceding.

Pittosporum bicolor, Hook., "Bonewood," "Whitewood."

The exudation of this species is a gum-resin which holds an essential oil incorporated with it. See Maiden (56).

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[1] See "Bibliography," at the end of paper.

GUTTIFERÆ.

Calophyllum inophyllum, Linn., "Ndilo Tree" of India; "Tumana" of the South Sea Islands.

This tree when wounded, exudes a small quantity of bright green gum, which is not collected, nor does it appear to be made use of in any way. (Dymock, *Materia Medica of Western India.*)

For a full account of this oleo-resin see Lauterer (33). Native of Queensland.

Calophyllum tomentosum, Wight, "Poon" or "Sirpoon" of India.

The gum of this tree is black and opaque, and much mixed with pieces of corky bark; it has a feebly astringent taste, and is very soluble in cold water, to which it yields a yellow-brown solution, exhibiting a strong blue fluorescence. If the gum is steeped in water for some time the solution becomes very dark in colour. . . I do not know whether this gum is applied to any industrial or medicinal use, but as it is collected by the natives of India it is supposed by them to have some medicinal virtue. (Dymock, *Materia Medica of Western India.*)

Lauterer (33) gives an account of the astringent gum of this tree collected iu Queensland.

MALVACEÆ.

The three Natural Orders Malvaceæ, Sterculiaceæ, Tiliaceæ all contain a gummy substance, and the twigs exude a slime when placed in water. The normal gum appears to resemble that of *Sterculia* gum and is white and horn-like; a red astringent gum is also found in these Orders.

Adansonia Gregorii, F.v.M., "Sour Gourd," "Cream of Tartar" tree, the "Gouty stem tree" of North-west Australia.

A dark red gum exudes from the fruit. (Bentham, *Flora Aust.*) "Upon the bark of these trees being cut, they yielded in small quantities a nutritious, white gum, which both in taste and appearance resembles maccaroni, and upon this bark being soaked in hot water, an agreeable mucilaginous drink was produced." (*Journ. of two Exped. of Discovery into N. W. and W. Australia*, Grey, p. 112.)

Bombax malabaricum, DC., the "Simool Tree," or "Malabar Silk-cotton Tree" of India.

The gum (Mocharas or Mucherus) only exudes from portions of the bark which have been injured by decay or insects; incisions in the healthy bark produce nothing. It is very astringent, and is used both by Hindus and Mahometans in diarrhœa, dysentery, and menorrhagia, in doses of from 40 to 50 grains an adult. (Dymock, *Materia Medica of Western India*). Waring (*Pharm. of India*), however says that this gum, or rather product of a diseased action, is incorrectly referred to this species, and that its botanical source is unknown. This astringent gum is further described by Lauterer (33). The tree is native of Queensland and Northern Australia.

Hibiscus heterophyllus, Vent.

Lauterer (33) gives an analysis of this gum. The small tree is a native of Eastern Australia.

Thespesia populnea, Corr.

A gum sent from Coimbatore (No. 2098) to London in 1873, is in irregular elongated tears of a dark pitchy-brown colour, shining, of the cherry gum kind, tasteless, but little soluble, swelling in water.

The Rev. J. E. Tenison-Woods writing on the occurrence of this tree in Northern Queensland, states that the rich yellow gum in the seed-vessels is like gamboge, and ought to be valuable. I believe, however, that its colouring matter is small, and of no value. It is a native of Queensland and Northern Australia.

STERCULIACEÆ.

For an account of the gum exuded by many species of Sterculiaceous gums, including exotic, see Maiden (41). For notes on Sterculia gums in general, see *Pharmacographia indica*, 228, also *Pharm. Journ.* [3], xx. 560, 868.

The mucilage of *Sterculia platanifolia*, (young shoots) consists of araban with some galactan, according to K. Yoshimura, *Bull. Coll. Agric. Imp. Univ. Tokyo*, 1895, 2,207. *Journ. Chem. Soc.*

LXX., (ii.), 60, and doubtless the composition of Australian Sterculia gums will be found to be similar.

In addition to the gums described in (41) I have seen gums from the following species, the composition and appearance of them appearing to be identical with those described.

Sterculia quadrifida, R.Br.

Brachychiton diversifolius, R.Br. (Syn. *Sterculia caudata*, Hew.) North-west Australia.

Brachychiton discolor, F.v.M. (*S. discolor*, F.v.M. and *S. lurida*, F.v.M.)

Brachychiton acerifolius, F.v.M. (*S. acerifolia*, A. Cunn.)

Tarrietia argyrodendron, Benth., "Buyong or Ironwood."

I have seen gum from this and the other New South Wales species and they appear to be all similar to one another and identical with *Sterculia* gum.

Heritiera littoralis, Dryand., a "Red Mangrove."

This tree yields a gum called "Mendora" in Ceylon. It is also a native of Queensland and Northern Australia.

TILIACEÆ.

Echinocarpus australis, Benth., "Maiden's Blush."

For an account of this gum see Maiden (47). Mr. Bäuerlen informed me that he has seen it used in the Big Scrub as a stiffener for straw hats.

Sloanea Woollsii, F.v.M., "Carabeen."

I have seen a similar gum from this species.

I have seen small quantities of a pale gum which swells up in water exuding from the following species of *Elæocarpus:*

E. reticulatus, Sm. (*E. cyaneus*, Ait.) Blue-berry.

E. obovatus, G. Don.

E. grandis, F.v.M., "Calhoun" or "Brisbane Quandong."

The Fijian *E. Storckii*, Seem., exudes a gum resin, on the authority of Mr. Storck, (Seemann, *Flora Vitensis*). This is the

first time I have heard of such a substance from this Order and it requires confirmation.

The *E. copalliferus*, Retz., of India is a synonym of *Vateria indica*, Linn., which of course belongs to the Dipterocarpeæ.

RUTACEÆ.

This Natural Order yields both gums and gum-resins. Maiden and Smith (63a) give an account of the following gums:—

Bosistoa sapindiformis, F.v.M.

Geijera Muelleri, Benth., "Axebreaker."

Melicope neurococca, Benth. (*Bouchardatia neurococca*, Baill.)

Pentaceras australis, Hook. f., "Scrub Hickory."

And of the following gum-resins:—

Medicosma Cunninghamii, Hook., "Glue gum."

To which I would add the following gum-resins.

Evodia accedens, Blume, of which I have seen a small quantity, not sufficient for chemical examination.

Zanthoxylum brachyacanthum, F.v.M., and

Evodia alata, F.v.M., which are both from Queensland.

Lauterer (33) has examined a resin from the latter species.

SIMARUBEÆ.

Ailanthus imberbifolia, F.v.M.

"From wounds in the bark a resinous substance exudes which burns with a brilliant flame." (Thozet, in *Report. Intercol. Exh. Melb.* 1886-7, p. 232) Queensland. It may be the following variety:—

Ailanthus imberbiflora, var. *Macartneyi*, Bail.

For a full account of the soft resin from this tree, see Lauterer (33.)

MELIACEÆ.

This Natural Order yields both gums and resins.

Cedrela australis, F.v.M. The "Red Cedar."

For a full account of the gum exuded by this tree see Maiden (40).

Lauterer (33) gives an analysis of this gum. It is considered by some botanists identical with the "Toon-tree" of India (*C. Toona*, Roxb.), hence the note of Toon Gum in *Pharmacographia Indica*, i. 339, 547, will be found of interest. It is worthy of note that a sticky aromatic resin exudes from cedar, *e.g.*, when a box or drawer is kept shut up, but only in small quantities. Native of New South Wales and Queensland

Melia Azedarach, Linn., (*M. composita*, Willd.) "White Cedar."

The tree yields a gum similar to that produced from the Acacia, plum and cherry trees; it may be collected in considerable quantity (Bennett). A specimen of gum, said to be derived from this tree, is in irregular tears, rather adhesive and dull, with a shining fracture, amber-coloured and brownish, rather friable, mixed with fragments of bark, tasteless, soluble in water. (Cooke, *Gums and Resins of India*.

I have seen a small quantity of gum from this tree. Lauterer (33) gives an analysis of it. The tree is found from New South Wales to Northern Australia.

Owenia venosa, F.v.M., "Bog Onion."

This tree exudes a small quantity of a gum and there is also a garlic odour of the foliage there being a resinous exudation of the young leaves.

Flindersia maculosa, F.v.M., "Spotted or Leopard Tree."

This is probably the tree referred to by Mitchell, in the following passage: "In the ground beyond the plains (near the Darling) . . . . and an Acacia, with a white stem, and spotted bark, there grows to a considerable size, and produces much gum. Indeed gum acacia abounds in these scrubs, and when the country is more accessible, may become an article of commerce." (*Three Expeditions*, i., 303.)

For an account of the gum arabic from this tree, one of our best soluble gums, see Maiden (38). Lauterer (33) gives an analysis of this gum.

Flindersia australis, R.Br., "Cudgerie."

This tree yields a small quantity of gum similar to that of *F. Bennettiana.*

Flindersia Bennettiana, F.v.M., "Teak."

The exudation is a true gum. The greater portion is soluble in cold water, little more on boiling, but the remainder is directly soluble in a very dilute soda solution. It consists of arabin with metarabin.

In this connection a note on the gum of *Khaya senegalensis*, a Meliaceous tree from Tropical Africa (*Kew Bulletin*, 1890, p. 169) will be found interesting.

CELASTRINEÆ.

Elæodendron australe, F.v.M.

Is a common tree of the Sydney district and eastern New South Wales in general, but I do not remember to have found gum on it. The genus, in other parts of the world, however, yields useful gums. For example, there is a gum of *E. orientale*, in the Mauritius, see *The Voyage of Francis Leguat*, i., 53, (*Hakluyt Soc.*).

Elæodendron glaucum, Pers., of India and Ceylon, would appear to be a desirable new edible gum. "Clear, brittle, light-coloured and soluble in water, forming a good mucilage. The absence of much ash, and adhesiveness and reactions of the solutions are favourable qualities and place it among the gums of the arabin class." (Report of the Officer-in-Charge, Econ. and Art section of the India Museum for the year 1900-1.)

SAPINDACEÆ.

Atalaya hemiglauca, F.v.M., "White-wood."

This tree exudes a useful pale-coloured gum. See notes on a gum of this tree collected by the Horn Exploring Expedition (62). Native of the interior of South Australia, New South Wales and Queensland.

I have seen gum exuded from *Nephelium sp.* (Northern Rivers), also from *Cupania semiglauca*, F.v.M., and *Cupania pseudorrhus*, A. Rich., the product being a hard, clear yellowish soluble gum in each case.

Dodonæa viscosa, Linn.

This common Australian shrub has not been credited in Australia with yielding a gum or a resin, but a resin in India is noted in *Pharm. Indica*, i., 372.

BURSERACEÆ.

Canarium Muelleri, Bail.

I have examined the oleo-resin of this tree; see (55). Dr. Lauterer (33) found amyrin in this oleo-resin and describes its composition at some length.

ANACARDIACEÆ.

Semecarpus Anacardium, Linn., "Marking-nut Tree" of India.

In India a brown, nearly insipid gum, exudes from the stem. It has otherwise been described as a "coarse black gum." We have a closely allied species (*S. australiensis*, Engler) in Queensland and Northern Australia.

The so-called Pepper-tree (*Schinus molle*), so largely cultivated in Australia, freely yields an aromatic resin which has formed the subject of research. It is alluded to in *Pharm. Journ.* 21st Oct., 1899, p. 377.

The *Garcinia collina*, Vieill., of New Caledonia yields a gum-resin comparable to Gamboge. Heckel and Schlagdenhauffen, *Rép. de Pharm.* [3] 5, 193; full abstract in *Pharm. Journ.* [3], xxiii. 989. The exudations of the trees of the South Sea Islands have a special interest for us. The genus *Garcinia* is represented in Queensland by an indigenous species.

LEGUMINOSÆ.

Acacia spp., "Wattle Gum."

My paper (44) is so comprehensive that it will be sufficient to add a few supplementary notes. Probably the best modern analysis of a Wattle Gum is that by Winthrop E. Stone of *A. decurrens.*

Wattle Gum undoubtedly possesses nutritive properties. According to Wilhelmi, the Port Adelaide tribes lived almost exclusively

during the summer months on the gum obtained from different *Acacias*, and the same was true of other tribes.

The following extract from the *Sydney Morning Herald* of the 24th March, 1891 is to the point:—Albury, Monday.—A little boy named Finch, who was lost on the 15th instant, was recovered yesterday by a black tracker engaged from Benalla. The child seemed thin, but was otherwise not much the worse for his eight days in the bush. He was found 10 miles from home, and said he had lived on wattle gum. Over 400 people had been in search of the boy all the week, and were just on the point of abandoning their pursuit as useless."

For a brief description of Wattle Gum see *Pharm. Journ.* [3], xx., 719.

Cherry Tree Gum is in Europe rendered soluble and decolourised by the addition of sulphuric acid (see *Pharm. Journ.* 29th Oct., 1892) and similar treatment may be applied to some of our less soluble wattle gums.

Acacia Bakeri, Maiden.

See Maiden and Smith (63*a*).

Acacia Cunninghamii, Hook.

Dr. T. L. Bancroft, states that in Queensland, gum of this species makes a good adhesive mucilage; it is, however, dark in colour. Lauterer (33) gives an analysis.

Acacia dealbata, Link., "Silver Wattle."

See Heckel and Schlagdenhauffen (17) for an exhaustive account of this gum. The species is said to yield a soluble gum in Java on the authority of Dr. de Vrij, (*Chem. and Drugg.*, Aug. 20, 1892, p. 260). Lauterer (33) gives an analysis of this gum.

Acacia decurrens, Willd., "Green Wattle," "Black Wattle."

The gum of this species contains a complex carbo-hydrate of the galacto-araban character, and does not differ essentially from gum-arabic, peach-gum or cherry-gum. Winthrop E. Stone (*Amer. Chem. Journ.* xvii., 196 – 199; see also *Journ Soc. Chem. Ind.*, July 1895, p. 667). Lauterer (33) gives an analysis of this gum.

Acacia harpophylla, F.v.M.

An astringent gum of this species is described by Lauterer (33).

Acacia leiophylla, Benth.

For an analysis of a sample collected by Mr. R. Helms of the Elder Exploring Expedition, see Maiden (61*a*).

Acacia Maideni, F.v.M., "Broad-leaved Sally."

See Maidèn and Smith (63*a*).

Acacia Oswaldi, F.v M., "Miljee."

This wattle yields a fair gum arabic. See Maiden and Smith (63*a*).

Acacia penninervis, Sieb.

Lauterer (33) gives an analysis.

Acacia retinoides, Schlecht.

See Maiden and Smith (63*a*).

Acacia salicina, Lindl.

"We found a curious willow-like *Acacia* with the leaves slightly covered with bloom, and sprinkled on the underside with numerous reddish minute drops of resin." (Mitchell, *Three Expeditions*, ii., 20.) This species also exudes a soluble gum from the bark. The genus *Acacia* therefore produces both a gum and a resin.

Acacia verniciflua, A. Cunn.

The original description of this species in Barron Field's *New South Wales* notes, "ramis junioribus viscidis." The species was also described under the name of *A. exudans*, Lindl., "the leaves being covered with a clammy exudation resembling honeydew." (Lindley in Mitchell's *Three Expeditions*, etc., 214.)

Adenanthera pavonina, Linn.

This tree yields in Ceylon a gum called "Madatia." It is also a native of North Queensland.

Albizzia procera, Benth., "Tee-coma of the aborigines of the Northern Territory."

This tree exudes gum copiously. It is in dull, horny-looking, roundish lumps, usually about the size of a marble. It requires

picking, as much of it is dark coloured and inferior. The dull appearance is only superficial, for it has a very bright fracture. It swells up in water to a large extent, and partly dissolves. The soluble portion is clear, and almost colourless. This gum differs in behaviour from such of the Acacia gums as are only partially soluble in water, in that a few hours after placing it in cold water it disintegrates, forming flaky masses, whereas the partially soluble Acacia gums, while likewise swelling up considerably, preserve a certain amount of cohesion for a day or two. It is found in Northern Australia.

Albizzia pruinosa, Benth., "Stinkwood."

See Maiden and Smith (63*a*) for an account of the partially soluble gum of this species.

Albizzia toona, Bail.

Lauterer (33) gives an analysis of this gum.

Bauhinia Carronii, F.v.M.

From incisions made in the trunk it exudes a large quantity of a yellowish, transparent, tasteless gum, of such wonderful tenacity that, before breaking, it will stretch to a length of two or three feet in threads so fine as to be almost invisible." (O'Shanesy, *Contrib. to Flora of Qd.*, p. 27.)

Bauhinia Hookeri, F.v.M.

Lauterer (33) gives an analysis of this gum.

Castanospermum australe, A. Cunn., "Moreton Bay Chestnut."

Gum shown in N. S. Wales Court, Paris Exh. 1867. What I have seen is a gum which swells up in water and but sparingly soluble. I have only seen it in small quantities. Lauterer (33) gives a note on it.

Derris scandens, Benth.

I have seen a small quantity of gum from this climber.

Erythrina indica, Lam., "Indian Coral Tree."

This tree yields a brown gum of no value. The species is not endemic in Australia. It is found in Queensland and Northern Australia.

Galactia varians, Bail.

Lauterer notes a resin in this plant in *Proc. R. S. Qd.*, xii., 93.

Kennedya rubicunda, Vent.

Mr. W. Bauerlen told me that he had seen traces of gum on a vine of *K. rubicunda* of unusually large size, fully an inch in diameter, on the Richmond River.

Lonchocarpus Blackii, Benth.

Lauterer (33) gives an account of this astringent gum.

Mezoneuron Scortechinii, F.v.M., "The Barrister."

This climber produces a tragacanthoid gum. See Maiden (45).

Mezoneuron brachycarpum, F.v.M.

I have seen a small quantity of a similar gum on this species.

Milletia megasperma, F.v.M., "Native Wistaria."

An astringent gum exudes from this climber. See Maiden (34). "A climbing plant, the stem of which is sometimes a foot in diameter, and which, when fresh cut, exudes a rich red resinous juice, which is very astringent. Not used for any purpose." (Charles Moore in *N.S.W. Catal. Paris Exh.* 1867).

Lauterer (33) gives an account of this astringent gum.

SAXIFRAGEÆ.

Ceratopetalum apetalum, D. Don., "Coachwood."

Ceratopetalum gummiferum, S.M., "Christmas bush or tree."

For an account of the astringent gums of these species see Maiden (39).

Schizomeria ovata, Don.

This tree is closely allied to *C. apetalum*, and the exudation appears to be similar. See Maiden and Smith (63*a*.)

Eucryphia Billardieri, Spach., "Leather wood."

In 1892 Mr. Alex. Morton wrote me as follows :—"I send you a box containing a few twigs of the 'Leather tree' or 'Pinkwood.' You will notice a good deal of gum on several parts. The men in the country districts say the gum has great healing qualities in cases of sore hands. I should be glad if you would let me

know what you think of it." As herbarium specimens were not forthcoming for years afterwards, I put the specimens aside. A native of Tasmania.

RHIZOPHOREÆ.

Rhizophora mucronata, Lam. A "Mangrove."

The blood red sap is much used by the natives of Fiji for dyeing their hair. Mixed with the sap of *Hibiscus moschatus*, Linn., it is used for painting crockery by the native potters. (Seemann, Flora Vitiensis.)

New South Wales to Northern Australia.

COMBRETACEÆ.

Terminalia sp.

"We collected a great quantity of *Terminalia* gum, and prepared it in different ways to render it more palatable. The natives, whose tracks we saw everywhere in the scrub, with frequent marks where they had collected the gum, seemed to roast it. It dissolved with difficulty in water; added to gelatine soup it was a great improvement. . . . But it acted as a good lenient purgative on all of us." (Leichhardt, *Overland Journey to Port Essington*, p. 374.)

"The Nut trees, a species of *Terminalia*, are very plentiful near here. . . . The gum of these trees is readily soluble in cold water, and is good to eat when pounded very small and dissolved; three large tablespoonfuls we found would make one quart of thick gum water. In appearance it is very similar to gum tragacanth." (Waterhouse's *Report on Stuart's Exped. in Northern Territory*.)

Terminalia Catappa, Linn.

Lauterer (33) has a note on this gum.

EUCALYPTUS KINO.

"The origin of the name Kino has not yet been satisfactorily ascertained. As stated by Dr. Pereira, it was introduced into the *Edinburgh Pharmacopœia* of 1774, as *Gummi Kino*, and into the *London Pharmacopœia*, in 1787, as *Resinæ Kino*. It was described under this designation in the third edition of Lewis'

Materia Medica, 1784, but in the second edition, 1768, it is described as *Gummi rubrum astringens*, from Gambia. I have long been of opinion that the name was derived from the Indian *Kuenee*, or *Kini*, applied to a similar exudation from the bark of *Butea frondosa*, of which the Sanscrit name is *Kin-suka*." (Dr. Royle, in *Pharm. Journ.*, V. 496.)

Yet, after quoting the above statement, Dr. W. F. Daniel, who, in describing the West African Kino-tree (*Pterocarpus erinaceus*), says:—"A more reasonable probability, however, exists that it was derived from the Mandingo *Kāno* or *Keno*, under which name it was first sold to the European traders by the natives, and exported by them by this aboriginal expression, and subsequently retained as a means of distinction from the other kinds of gum brought from the same localities." (*Pharm. Journ.* xiv. 60).

I have not been able to find a passage which throws more light upon the subject. The general opinion of the authors of dictionaries, however, is that the word is of East Indian origin. According to Bentley and Trimen (*Medicinal plants*), the term Kino is only strictly applicable to juices inspissated without artificial heat, and not extracts. The use of the term to Eucalyptus exudations is now of long standing; Mr. Smith and I have a note on the subject, this *Journal*, xxix., 409.

The oldest reference to Eucalyptus Kino is as follows:—"Most of the trees that we saw are dragon-trees as we supposed; and these too, are the largest trees of anywhere. They are about the bigness of our large apple trees, and about the same height; and the rind is blackish, and somewhat rough. The leaves are of a dark colour; the gum distils out of the knobs or cracks that are in the bodies of the trees. We compared it with some gum dragon, or dragon's blood, that was aboard, and it was of the same colour and taste." (Dampier's Voyage to N. W. Australia in 1687-8, quoted in Major's "Early voyages to Terra Australis," *Hakluyt Soc.*, p. 101). Perhaps the following also refers to Eucalyptus in spite of the "prickles and thorns." . . . . the place where

we were had been planted with a good many shrubs, among which were some quite three and four fathoms thick, but bearing no fruit,—in short, full of prickles and thorns. Several of these yielded a gum nearly like wax, of a brownish red colour." *Op. cit.* p. 125.

De Brosses in 1756, quoted by G. B. Barton observed that in the continent were found "trees yielding a gum like dragon's blood," —probably following Dampier.

An Officer of Marines writing to Sir Joseph Banks in 1788 stated, "The country produces five or six kinds of trees, two of which produce the same sort of gum, viz.: a red astringent gum well-known in England." (Barton, *History of N. S. Wales*, i., 504).

Part i. *Ruby Group.*

Following are additional notes to those contained in my special notes (57) on this group. Old ruby and gummy kinos are often much like lignite in appearance.

Eucalyptus acmenoides, Schau., "White Mahogany."

This kino occurs in small quantity only, is of an amber colour when recently exuded, passing subsequently to red and black. (Bancroft). I have never found enough for a full analysis although I have searched for it for years.

New South Wales and Queensland.

Eucalyptus Baileyana, F.v.M., *Fragm.* xi., 37.

"The kino of this species contains about 35 per cent. of gum." *(sic)*, Mueller, *Eucalyptographia.* I did not find gum in a sample I examined.

Northern New South Wales and South Queensland.

Eucalyptus hæmastoma, Sm., var. *micrantha*, Benth., and

Eucalyptus Planchoniana, F.v.M.

See Maiden and Smith (63*a*).

Part ii. *Gummy Group.*

Following are additional notes to those contained in my special notes (57) on this group.

It appears singular at first sight that whereas all the kinos of this group are practically entirely soluble in cold water, the amounts capable of solution in alcohol vary much. I have found by experiment that these variations are owing to the quantity of kino-tannic acid taken up by the alcohol, and the only explanation of this which appears satisfactory is that in some kinos the bond which unites the tannic acid with the gum appears to be looser than in others, in other words, is less entangled in the gum particles, so that in some the alcohol is capable of dissolving out more tannic acid than in others.

Whether age is an element in the matter or not, I cannot yet venture to say, as the specimens of the gummy group in my possession are too few, and, since in this group cold water is but of little aid in fixing the age of a kino, I am deprived even of this assistance in coming to a conclusion in the matter.

Eucalyptus saligna, Smith, "New South Wales Blue Gum."

Kino appears to be very scarce in this species, in fact settlers will tell you it yields none. I have only collected it in little blisters on old trees, and an old bushman "never knew it had any gum," although he often cut it up for felloes. New South Wales and Queensland.

The Ironbark kinos all belong to the Gummy Group, and Mr. Forester Allan writing to me says:—"I obtained the gum from the Ironbark by boiling the bark and straining the liquor, after which I reduced it to a thick consistency. Large quantities can be obtained by this process at little cost."

Part iii. *Turbid Group.*

Following are additional notes to those contained in my special notes (57) on this group.

Eucalyptus corymbosa, Sm., "Bloodwood."

Lauterer (33) examines this kino at length. Bloodwood kino was formerly used by the blacks for tanning skins of animals. The *modus operandi* was to skin the animal, put in the kino and

some water, tie up and shake vigorously and let stand until the tanning is complete.

Incidentally I may mention that the young leaves of the Bloodwood if pulled asunder contain a substance which appears to be identical in its physical properties to india-rubber; it can be readily drawn into long threads. I am not aware that it has been chemically examined. New South Wales and Queensland.

Eucalyptus incrassata, Labill.

For analyses of the kinos of mallees belonging to this species, collected by the Elder Exploring Expedition, see (61*a*).

Eucalyptus leucoxylon, F.v.M., "Blue Gum of Victoria and South Australia."

The kino is easily soluble in water, is of slightly acid reaction, becomes turbid, but clear again on heating. (*Eucalyptographia*). Victoria and South Australia.

Eucalyptus maculata, Hook., "Spotted Gum."

Lauterer (33) examines this kino at length. Spotted Gum kino is used in the bush for toothache, and squarers use it to cure sores and cuts. Victoria to Queensland.

Eucalyptus microcorys, F.v.M., "Tallow-wood."

Lauterer (33) also examines this kino at length. New South Wales and Queensland.

Eucalyptus tesselaris, F.v.M., "Carbeen."

For an analysis of this Kino collected by Mr. R. Helms of the Elder Exploring Expedition see (61*a*).

"At times one finds a woolly mass in partially burnt logs, which is found to be a white crystalline body, like benzoic acid. This substance may be revolatilized and collected of a pure white colour, under a cold bell-glass. It has the pleasant odour of benzoin, but has not been further investigated." (Dr. J. Bancroft). Lauterer (33) examines this kino at length. New South Wales and Queensland.

The following notes on Eucalyptus kinos show the state of the chemistry of the subject prior to researches begun by myself,

which have been continued and valuably improved by my late assistant, Mr. H. G. Smith.

"Dr. A. T. Thomson describes four different kinds of kino, under the names of African, Botany Bay, Jamaica and East Indian or Amboya kino. To the second of these the Botany Bay kino, which is the product of the *Eucalyptus resinifera*,[1] or *iron-bark tree*, he ascribes the property of forming a tincture which gelatinises on keeping."

"Dr. Pereira also in alluding to this property in tincture of kino, says "where this occurred, probably the Botany Bay kino (inspissated juice of the *Eucalyptus resinifera*) had been employed." Pereira further states with regard to this species of kino, "that when digested in cold water, it swells, becomes soft and gelatinous (like red-currant jelly), and yields a red liquid which reddens litmus, and yields precipitates with lime water, gelatine, acetate of lead, sesquichloride of iron, and, if caustic potash or ammonia be previously added, with the chloride of calcium. Alcohol and emetic tartar occasion no precipitate. Digested in rectified spirit, Botany Bay kino becomes gelatinous as with water, and yields a similar red solution, from which water precipitates nothing, but which reddens litmus, and deposits a copious precipitate when potash, ammonia or lime-water is dropped in. From these and other experiments (says Pereira), I infer that Botany Bay kino consists principally of pectin and tannic acid." (Redwood in *Pharm. Journ.*, i. 399).

The following abbreviated remarks on some qualitative experiments with some Eucalyptus kinos are to be found in the *Report on indigenous vegetable products, Victorian Intercolonial Exhibition*, 1861:—"The aqueous solutions of the Eucalyptine gum-resins all give an acid reaction with test paper; but the differences in the behaviour of each, when dissolved by water, subjected to the several reagents, become very manifest. The precipitate caused by a solution of gelatine indicative of tannic acid does not appear

[1] A very old error in nomenclature as shown.

in any case to correspond in quantity with their intense astringent taste; and occasionally the addition of that substance causes no precipitate at all. This fact has an important bearing upon the value of this whole class of bodies under consideration for tanning purposes, and as substitutes for catechu and similar bodies.

"With acetate of lead these astringent bodies give copious gelatinous precipitates, and with the salts of iron various shades of green and black. The mineral acids also determine in them bulky flocculent precipitates." . . . "The solvent action of water on these bodies is not the same in the case of gums from different species of trees. If for instance cold water is poured on the produce of *E. corymbosa*, whether it be in the solid or liquid state, a portion only is taken up, while the gum from the stringy-bark is completely dissolved. When as in the case just cited, a flocculent residue remains after the action of water, a few drops of ammonia render the solution perfect."

By far the fullest experiments on Eucalyptus kinos hitherto made are those of Prof. Wiesner of Vienna, published in the *Zeitschr. d allg. oesterr. Apotheker-Vereines.* (Wien, 1871). *Pharm. Journ.* [3] ii. 102. Following is a brief extract:—

"These samples show a pretty uniform reaction; they all give with sulphuric acid a pale-red, flocculent precipitate; the aqueous solution *always*[1] gave with perchloride of iron a dirty green precipitate, *with the exception* of *E. obliqua*, which gave a dark violet coloration. . . . Well known authorities in pharmacognosy have been inclined to doubt the kino-like character and to look upon it merely as a gum-resin impregnated with colouring matter. It therefore became necessary to determine the constituents of Eucalyptus gum; and the author finds the principal part of all samples to be nothing but so-called kino-tannic acid. He obtained by Berzelius' method a red, amorphous substance identical in all its reactions with kino-tannic acid.

[1] The following being among the species examined by Prof. Wiesner, *E. amygdalina, piperita, leucoxylon, pilularis,* together with varieties of *amygdalina,* these generalizations will not hold good. The italics are mine.

The gum was dissolved in water, and the flocculent, pale-red precipitate obtained by adding sulphuric acid, was washed until the acid reaction of the wash-water ceased; the precipitate was dissolved in boiling water, and separated after cooling from the insoluble matter. The red liquid was evaporated in vacuo and yielded thin, red, transparent laminæ, which under the microscope appeared cracked, and quite amorphous. The mass is slowly soluble in cold but readily in hot water; the solution is astringent. Alcohol, like hot water gave a ruby coloured solution; perchloride of iron produces a dirty green precipitate. The kino-tannic acid obtained from kino itself gave with the iron-salt a black-violet precipitate; but as the author is far from looking upon this acid as a definite chemical compound, he thinks he has proved the identity of the principal constituent of the gum under examination with kino. He adopts the name Eucalyptus kino, and avoids the expression gum, because[1] gums are mostly soluble in alcohol as well as in water. In Bentham and Mueller's "Flora Australiensis," the many extracts obtained from Eucalyptus are always called gums, and in Vol. iii. 185, it is even stated that the Eucalyptus species yielded gum-resins, and therefore they were named gum-trees.[2]

"Pterocarpus kino contained, besides kino-tannic acid, water, mineral substances, with 13 per cent. of ash, a substance similar to pectine, catechine and a little pyro-catechine, but no sugar. Eucalyptus kino contained from 15 to 17 per cent. of water; it gave only a trace of ash, and no sugar was found. Several samples contained a little catechine. Pyrocatechine appears always to be present. A pectine-like substance could not be detected in any of the samples, but several samples contained a substance soluble in water, similar to gum arabic. The juices of *E. gigantea*, Hooker, (*E. obliqua*, L'Hérit.) contained this substance in such quantity that several lumps were quite insoluble in alcohol.

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[1] The word "these" is obviously omitted here.

[2] They are called gum-trees by reason of these exudations, and it is very excusable for Bentham, who was not a chemist, to call them "gum-resins." Neither are they "extracts."

"The physical properties of Eucalyptus kino nearly agree with those of ordinary kino; it forms dark red, more or less transparent grains; in thin fragments, under the microscope, quite transparent and amorphous. They sink in cold water. Its specific gravity is 1·110; after complete expulsion of the air 1·140. Water dissolves it more or less readily to a red, yellowish or brownish liquid of astringent taste. Shaken with water, all samples give a frothy solution."

In the "Eucalyptographia," under *E. longifolia*, Baron von Mueller collects together in tabular form the percentages of kino-tannic acid in the bark (not in the kino) of various species of Eucalyptus. In a paper in the *Pharm. Journ.* [3] xvi., 898 under "*Eucalyptus Kino*" this table is reproduced, but entitled, "The amount of the astringent exudation afforded by different species," a sentence which is not only incorrect, but which, (since the expression *per cent.* is used) appears devoid of meaning.

I have not been able to find the following papers in the colony:

1. "On the astringent principle of kino." T. Gerding, *Chem. Gaz.*, 1851, 261.

2. "On Kino." H. Eissfeldt, *Ann. Ch. Pharm.* xcii., 101.

They both refer to the official kino, but they are probably most useful, and I have only been able to obtain a detached statement or two from their contents.

Angophora intermedia, DC., One of the "Rough-barked Apples."

Bees industriously remove this and other apple-tree kinos in the viscid state.

For a full account of this kino see Maiden (60), and of the liquid kino see (50). As regards the latter, the statement is made in the N. S. Wales Catalogue, Paris Exhib. 1867, that "Apple tree juice is used as a varnish."

Angophora lanceolata, Cav., "Smooth-barked Apple."

For a full account of the kino see Maiden (60) and Lauterer (33).

Angophora Woodsiana, Bail.

See J. Bancroft, quoted by Maiden (60).

Spermolepis gummifera, Brongn. and Gris.

Also belonging to the Myrtaceæ, is from New Caledonia and yields a kino. See *Rép. de Pharm.* [v.] (3) 241 *(Journ. Soc. Chem. Ind.* xii. 611).

Syncarpia Hillii, Bail.

Lauterer (33) has examined this oleo-resin and his paper should be referred to. Queensland.

Syncarpia laurifolia, Ten., "Turpentine-tree."

Is a better known species than the preceding, and its oleo-resin has often been collected. It has been partly examined by Prof. E. H. Rennie of Adelaide, who obtained an acid from it, by boiling with potash, which is not cinnamic acid, but other duties have prevented the completion of the research. It is stated that the native bees use the oleo-resin for the purpose of varnishing the interior of cavities in trees before starting to build their nests. It is a substance of special interest for its own sake, apart from the fact that it is one of the few exudations from our Australian Myrtaceæ that are not kinos.

New South Wales and Queensland.

ARALIACEÆ.

Astrotriche floccosa, DC.

For a note on a gum-resin from this shrub see Maiden (46).

Panax elegans, C. Moore and F.v.M.

Panax sambucifolius, Sieb.

For an account of these soluble gums see Maiden (46). This paper contains notes on other exudations belonging to the Araliaceæ. A resinous substance from the bark of *Aralia spinosa*, is recorded in *Pharm. Journ.* [3] xiii. 305.

LORANTHACEÆ.

Nutysia floribunda, R. Br., "Cabbage Tree," "Mote-yar" of the blacks (Stokes), "A Mistletoe."

The gum from this tree is said to make good adhesive mucilage. It was sent from Perth to the Colonial and Indian Exhibition, 1886, and was thus reported upon, . . . "is a tragacanth-like gum, which swells in water but does not dissolve. It might, perhaps, be made to serve as a stiffening material for the calico printer." It is a native of Western Australia.

Rubiaceæ.

Gardenia resinosa, F.v.M.

Occurs in Australia (Northern Territory), and hence the exudations of Gardenias are of interest to us, particularly those from the South Sea Islands.

The following note by Mueller in *Rep. Intercol. Exh. Melb.* 1886-7 is interesting. The species is doubtless one of those referred to by Heckel in later years.

"*Gardenia Resin from New South Wales.*"—"The species of Gardenia yielding this resin remains as yet phytographically unknown. It is probably allied to a species discovered by myself in North Australia, *Gardenia resinosa*, so called on account of its large amount of resinous exudation. The resin from New Caledonia had evidently been fused; it is brittle. On fracture, it presents a yellowish colour; it is tasteless but possesses an odour reminding one of ginger. When leniently heated it assumes a waxy consistence. It dissolves almost without residue in cold alcohol, and contains, therefore, only a trifle of gummy substance. The alcoholic solution is limpid and yellow, rendered milky by addition of water. When dissolved in boiled alcohol it forms after cooling a large deposit. Evaporation of spirit leaves a pellucid, greenish-yellow resin. This pure resin dissolves in ether, oil of turpentine, and partly in strong alkaline solutions."

"And again, "*Ouliépé* is a New Caledonian resin obtained by mastication of the buds of *Gardenia ouliépé*, Vieill., *edulis*, Vieill., and *sulcata*, Gærtn.; it is used by the natives for cement and caulking ships; it has a yellow colour, an aromatic disagreeable taste and a glossy fracture. It is met with in compact lumps, it

is obtained from the lumps as a yellow powder from quickly dried leaves and pounding them. Soubeiran thinks the Ouliépé resin is similar to Decamali from East India obtained from *Gardenia gummiflora*, and *lucida*, Roxb., and there used in the hospitals as a covering for wounds to protect them from insects and to absorb the smell from ulcers.

"The last mentioned resin is often taken for Elemi." *Journal de Pharm. et de Chim*, March, 1870, p. 242. (*Pharm. Journ.* [3] ii., 403).

Heckel and Schlagdenhauffen describe the resin enclosing the leaf-buds of *G. Ouliepe*, *G Aubryi*, and *G. sulcata*. *Rép. de Pharm.* [3] 5 (xlix.) 145 (1893). Full abstract in *Pharm. Journ.* [3] xxiii. 988 and *Journ. Soc. Chem. Ind.*, Jan. 1894, p. 47.

SAPOTACEÆ.

Sideroxylon australe, Benth. and Hook., f., (*Achras australis*, R.Br.), "Black Apple."

The remarkable gum which exudes from our *Achras australis* is worth investigation. I can answer for its disagreeable tenacity when it gets about the hands." (*Tenison-Woods, Proc. Linn. Soc. N.S.W.*, iv. 135). The juice is milky and the Order to which this tree belongs yields the Gutta Percha of commerce. It would not be difficult to collect a quantity of this juice for research, and it should certainly be examined.

APOCYNEÆ.

Tabernæmontana macrophylla, (? Poir.).

A gum resin from this species from New Caledonia was exhibited at the Paris Exhibition, 1867. I have not heard of the occurrence of a similar exudation in any Australian Apocyneæ.

GOODENIACEÆ.

Leschenaultia divaricata, F.v.M.

For a note on a gum extracted from the roots and used by the aborigines as a cement, see Horn Expedition (62).

MYOPORINEÆ.

Myoporum platycarpum, R. Br.

For an account of this resin see Maiden (53). Lauterer (33) has also given an account of this resin.

The following unpublished note is by the late K. H. Bennett of "Ivanhoe," viâ Hay:—"Another substance called by the natives "Tecabalah," and resembling pitch or wax exudes from this tree at certain times of the year. When it first exudes it is soft and very tenacious and exactly like wax, and assumes the form of drops, varying in size from that of a pea to that of a nut, these gradually harden by exposure to the air and eventually are found lying around the foot of the tree. This substance is used by the blacks for the same purposes as we use wax, and answers just as well, it merely requires heating."

VERBENACEÆ.

Avicennia officinalis, Linn., "Mangrove."

Forster erroneously supposed this species to produce a resin, which led him to describe it as *A. resinifera*, (Kirk). See *Agathis australis*, *infra*.

MYRISTICEÆ.

E. Schauer has described a new kino from *Myristica*. *Pharm. Journ.* [iv.] 3, 117. *Journ. Chem. Soc. Abstr*, lxxii., 278. It should be looked for in our *M. insipida* of the Northern Territory.

MONIMIACEÆ.

Atherosperma moschata, Labill., "Sassafras."

The resin contained in the bark of this tree has been examined by Zeyer (*Pharm. Viertelj.*, x., 517), an abstract of whose paper appears in Gmelin's *Handbook*. The following is his account of it. The bark previously exhausted in water, is exhausted with very weak caustic potash; the solution is allowed to stand till clear, and the resin is precipitated by hydrochloric acid. The precipitate is indigested with alcohol, the extract evaporated, and the residue boiled with water, and dried. Brown-red, melts at 104° C. Dissolves easily in caustic alkalies and their carbonates,

from which it is precipitated by acids, and also in alcohol, but it is nearly insoluble in ether. Contains at 100° C., on the average 69·38% C, 8·85% H, and 21·77 O, corresponding to the formula $C_{8}H_{32}O_{10}$. A modern analysis is desirable.

Tasmania, Victoria and New South Wales.

PROTEACEÆ.

It will be observed that this is one of the orders which yields both gums and resins.

Banksia serrata, Linn. f., "Red Honey-suckle."

A dark red gum (? resin) has been observed on this species. See Maiden (42). "The Banksia wood, which produces large quantities of resin." . . . (Note on the vegetation of W. A. by A. H. Robertson, M.D.) in *Prize Essays Edinburgh Forestry Exh.* 1884.

Grevillea robusta, A. Cunn., "Silky Oak."

For an account of a gum and gum-resin from this well-known tree see Maiden (42). Lauterer (33) also gives an account of this resin. A research on the interesting exudation from this well-known species is a desideratum.

The substance was exhibited in the New South Wales Court, Paris Exhibition, 1867. In this connection see a paper, this *Journ.* 1896, p. 194, by Mr. Smith on the sap of *G. robusta*.

Following are some notes on the exudation by Mr. W. Bauerlen who collected it for me on the Northern Rivers :—"When quite fresh and soft it is of a peculiar yellow colour, but on hardening it assumes something of a flesh or wine colour. It has an extremely disagreeable smell. . . . The local opinion is that there is more gum during very rainy weather than during drier times. The country people look upon it as a nuisance as it sticks to the horses' manes when they rub themselves against the tree."

Grevillea striata, R. Br., "Beefwood."

For an account of the gum-resin of this species see Maiden (42). The Western (Q.) blacks make use of the resin of *G. striata* to

manufacture a kind of asphalt wherewith to cement on flints to the adzes and carvings. (Dr. T. L. Bancroft in a letter to me).

Dr. Lauterer (33) has also examined the resin from this tree.

Hakea acicularis, R. Br.

Hakea Macræana, F.v.M.

For an account of the gums exuding from these plants and from *Hakeas* generally see Maiden (42).

I have noticed jelly at the roots of *Hakeas* either where the bushes have blown down or not, or on the stem, where insects have attacked or otherwise injured them, forming a transparent ooze.

Macadamia ternifolia, F.v.M., "Queensland Nut."

I have seen a small quantity of exudation similar to that of *Grevillea striata* from a log of this species.

Persoonia linearis, Andr.

For a note on a dark red gum (? resin) from this species see Maiden (42).

Stenocarpus salignus, R. Br., "Beefwood," "Red Silky Oak" etc.

For a note on a gum from this species see Maiden (22).

Stenocarpus sinuatus, Endl., "Yiel Yiel," "Fire tree."

I have seen a small quantity of a reddish gum (?) from this tree.

Xylomelum pyriforme, Knight, "Native Pear."

For an account of the gum yielded by this small tree see Maiden (42).

THYMELACEÆ.

Pimelea.

The numerous Pimeleæ are perhaps of greater significance as medicinal plants, (than fibres). The acridity of their bark is more or less analogous to that of *Daphne mezereum;* the bark of *Pimelea stricta*, Meissn., from St. Vincent's Gulf being the most acrid of all. The proportion of acrid resin on which the blistering properties depend has as yet not been ascertained in any of our species. (Mueller in *Rep. Intercol. Exh. Melb.*, 1866-7, p. 255.)

EUPHORBIACEÆ.

Aleurites molluccana, Willd., "Candle-Nut Tree."

"A gum is produced from this tree, both spontaneously and on incisions being made in the trunk; it is of a yellowish or amber colour, inodorous and tasteless; the natives of the South Sea Islands chew it, but the suspicious family to which it belongs ought to make them cautious in its use. I tried it, however, as a mucilage for the suspension of some balsams, and no ill-effects arose from it." (Bennett). This species would appear to be one from which both a gum and a resin are obtainable. Queensland.

Baloghia lucida, Endl., "Scrub, or Brush Bloodwood," "Nun-naia" and "Dooragan" of the aborigines.

A blood-red sap oozes from the trunk when cut, and was obtained in the following manner in Norfolk Island:—"A knife, similar to a farrier's is used, but stronger, fixed upon a handle four to five feet long, which enables the workman to reach high up the trunk of the tree. A perpendicular incision is made through the bark, an inch wide at the surface, but tapering to a point near the wood, and from eight to ten feet long, forming the main channel through which the sap flows to the base of the tree, where a vessel is placed for its reception; branch channels are cut on each side of the main one, leading obliquely into it, six or eight inches apart, and extending nearly two-thirds round the trunk. The sap generally flows from the channels for about twelve hours, when it is collected. The quantity produced by each tree varies; sometimes about a pint, but on an average about half that quantity. The sap forms an indelible paint, and was formerly used in the island for marking bags, blankets, and other articles." (Shepherd.)

I have seen the inspissated juice collected from New South Wales trees. Lauterer (33) gives an analysis of this substance. The tree is native of New South Wales and Queensland.

Bertya Cunninghamii, Planch.

The branchlets of this tree exude a clear gum-resin so abundantly as to give dried specimens, when held up to the light, a pretty

hyaline appearance. The substance is of a yellowish colour, and no doubt would prove exceedingly interesting if examined, but the author has, up to the present, been unsuccessful in obtaining a quantity of it. It has a pleasant bitter taste, something like wormwood.

Many of our Euphorbiaceous plants yield resin in greater or less quantity, and will provide useful material for future experiment.

Beyeria viscosa, Miq., the "Pink Wood" of Tasmania, also called "Wallaby Bush."

A resinous substance exudes from the leaves, sometimes so abundantly that characters can be traced in it by means of a style.

As we have an Australian *Macaranga*, the following references will be useful:—

1. Macaranga Kino (*Pharm. Journ.* 18th May 1901, p. 617).
2. *Macaranga ferruginea*, Baker. A tree whose stems contain an abundant supply of resin, the nature of which requires investigation. Madagascar, (*Kew Bulletin*, 1890, 210.)

URTICEÆ.

Latex. The substance referred to in the following paragraphs is neither a gum nor a resin but belongs to what may be termed the "India-rubber group." It consists of a dried milky juice or latex (of which examples are afforded by other Natural Orders common enough in Australia, *e.g.*, Euphorbiaceæ and Asclepiadaceæ). For information in regard to the physiology of the subject see "Botany" by Sachs (Vines), pp. 85, 94, etc.

Ficus macrophylla, Desf., "Moreton Bay or Large-leaved Fig."

Specimens of the juice of this well-known tree which I caused to be sent to Kew for report in 1894 are reported upon (8), and the correspondence is interesting to those who may be tempted to incur expense in experimenting with it as a rubber producer.

Experiments at the Hamma Garden to obtain a coagulable latex have been abandoned, only negative results having been obtained. (*Rev. des Cult., Coloniales*, 20th Sept. 1901, p. 188). See also *F. rubiginosa*, which yields a similar juice.

Ficus rubiginosa, Desf., "Port Jackson Fig."

This fig, like others of the genus, exudes a juice when the bark is wounded. It is put to no useful purpose. It has formed the subject of De la Rue's and Miller's chemical investigation (73).

The official catalogue of the N.S.W. Exhibits (Paris 1855), contains the following information in regard to this particular specimen:—"Perforated waxy substance, exuded from the bark of native fig *Ficus ferruginea;*" (an obsolete name, and the substance is attributed by Sir William Macarthur to *F. rubiginosa)*, exhibited by W. Stephenson, Esq., Surgeon. From the Manning River. "A remarkable substance, possessing the properties of gutta-percha and bird-lime combined, and which can be obtained in the colony in any quantity. It softens by heat like gutta-percha, and like that substance can be moulded while warm into any shape, which it retains when cold, but becomes brittle. When very hot it is so strongly adhesive that it cannot be touched by anything without sticking most obstinately to it."

Mr. P. L. Simmonds said of the specimen, "An elastic gum-resin from an Australian Ficus was shown at the Paris Exhibition of 1855 in the New South Wales collection, in small tears of a dingy appearance, which might prove useful. A large portion dissolves in warm linseed oil, but spirits of wine does not act readily upon it. By mastication it becomes tenacious and bleaches thoroughly."

From the above and from statements in the original paper there is no doubt that the substance acted upon was picked already dried from the trees, and, on account of the delay in experimenting upon it, it was a very old specimen when analysed. I procured a small quantity of the milky juice (latex) of this species, and obtained it *quite fresh.* It was obtained in the spring by auger holes well through the bark. Whether a tree will yield any liquid at a particular time is very uncertain, and can be ascertained only by tapping. It apparently in no way differs from the "Moreton Bay Fig" juice *(F. macrophylla)*, so

familiar to people in New South Wales. It was of the consistency and colour of thick cream and perfectly homogeneous when freshly exuded. It gradually separates into two layers, a lower creamy or grey-colored portion, and a brown liquid of hardly higher specific gravity than water. Both layers continue to darken in colour. Analysis of this milky juice, completed within a month of exudation, remains a desideratum. A specimen I sent to Prof. E. H. Rennie, of Adelaide, was examined by him and Mr. Goyder (71).

LILIACEÆ.

Xanthorrhœa spp. "Grass Tree Gum."

I believe my paper on the aromatic resins known as Grass-tree Gum in *Agric. Gazette* (49) will supply sufficient information for most enquirers. It contains an extensive bibliography of the subject.

See also K. Hildebrand (18), Tschirch and Hildebrand (83), Schimmel (74), the "Garden and Field" (Adelaide), July, 1894, p. 64; the *Chemist and Druggist of Australasia*, of 11th December, 1897, p. 923, recording some Imperial Institute researches; and the same journal for February, 1898, p. 63.

At the junction of Berowra Creek with the Hawkesbury River I found (27th April, 1889) a true *gum* exuding from aborted (through insect punctures) flowering-spikes of this species. A larger quantity was also found on the caudices of other individuals and some samples exhibited now show a resin ("grass tree gum") and a true gum in close juxtaposition. This is another example of the few instances in which the sample genus is capable of yielding both a gum and a resin.

Xanthorrhœa Preissii, Endl.

For a partial examination of this Grass-tree Gum, collected by the Elder Exploring Expedition, see (61A). It is a native of Western Australia.

CASUARINEÆ.

Casuarina Decaisneana, F. v. M.

For a brief examination of this kino, collected by the Horn Exploring Expedition, see (62). Kino in this genus is rare, and the reference to the gum (kino) of *C. equisetifolia (Pharmacographica indica*, 375) will be useful.

GRAMINEÆ.

Triodia pungens, R. Br.

For an examination of this grass, collected by the Horn Exploring Expedition, see (62). See also my paper on Spinifex Resin (52).

"Samples of resinous matter from roots of Spinifex and tunnels made by ants, found here for the first time lying on the surface of the sandy ground between the bunches of Spinifex, apparently made of sand cemented with some agglutinous secretion of the insect, or what is more probably the resinous substance found at the roots of the Spinifex plant." [W. T. Tietkens' Exploration of West Central Australia, in *Trans. R.G.S. (Vict.)*, viii. 35].

CYCADEÆ.

Macrozamia spp.

My experiments and subsequent observations tend to show that the gums of all members of this genus are identical in character. See (43).

I note that the gum of *M. Denisoni* was exhibited in the N.S.W. Court, Paris Exhibition, 1867.

CONIFERÆ.

Agathis australis, Salisb. (Syn. *Dammara australis*, Lamb.)

The chewing of the fresh gum-resin of the Kauri Pine by the New Zealanders explains the error made by Forster (from Crozet, *Voyage de M. Marion*), who had named the Mangrove (*Avicennia officinalis*) *A. resinifera*, believing that the gum chewed by the natives had been obtained from that tree. The error is repeated by Lindley, *Vegetable Kingdom*, p. 665 (Colenso, in *Trans. N.Z. Inst.*, Vol i., *Essay on the Botany of the North Id. of N.Z.*, p. 56).

For an analysis of the New Zealand Kauri "gum," see Rennie (70).

The genus *Agathis* and its resin is of so much interest to us in Australia that I give the following unpublished letter from me to the Director of the Royal Gardens at Kew, dated 8th July, 1892:—

"In article cxciv. (March, 1891) of the Kew Bulletin, you desire to settle the origin of a supposed Dammara resin in the Kew Museum which came from Canala, in New Caledonia.

"Mr. J. Brazier is a resident of Sydney well known to me. Some five or six years ago he gave me samples of resin which he obtained from Canala, telling me that he had given the rest to Professor Moseley years back. He informed me that your sample and mine came from the same tree, and formed part of a larger mass which he picked off the bark. The resin is palpably from a *Dammara* when examined. He said it was from a very high tree, whose trunk was so long that he could not obtain a twig. He was certain the tree was not an *Araucaria;* the resin also is different from that of *Araucarias.*

"Like you I have arrived at the conclusion that it was obtained from *D. lanceolata*, and following are my notes on the subject, for I have taken an interest in the resin:—

In *Plantes utiles de la Nouvelle Calédonie*, by E. Viellard, 8vo. pp. 76, are some notes on *Dammaras*. "*D. Moorei*, Lindl. Cette conifère acquiert des proportions gigantesques; son tronc droit, sans branches, s' élêve á 30 et 40 métres de hauteur et mesure souvent 1·50 m. de diameter. . . *D. ovata*, Moore. Tronc trés rameux et généralement moins élevé que le précédent. . . . Le *D. lanceolata* différe du *D. ovata* par son tronc plus robuste. . . . Peu commun dans les bois des montagnes à Kanala."

"Ainsi qu' on peut le voir, chacune de ces trois espéces a sa zone de végétation. Le *D. Moorei* habite la partie nord de la Calédonie. Le *D. ovata* le sud, et enfin le *D. lanceolata* les montagnes du centre.

"Du tronc de ces arbres découle en abondance une résine. . . connue dans le commerce sous le nom de Kaori (the French spell-

ing of the better known Kauri gum or resin from *D. australis* of New Zealand). Les indigènes de la Nouvelle-Caledonie se servent de cette substance pour vernir les poteries grossières qu' ils fabriquent."

The information as to *D. lanceolata* being found (principally or solely) in the neighbourhood of Canala, and Mr. Brazier's description of the tree being very large tends to show the origin of the resin. Without some such evidence I would submit that the precise species could not be determined as there is much similarity in the resins exuded by the different species of the same coniferous genus, *e.g.*, *Araucaria*, *Frenela*, (*Callitris*), *Dammara*.

Kaori resin has been sent from New Caledonia to several International Exhibitions. Thus "Resine de Kaori, *Dammara ovata*" was sent to the London Exhibition 1867 (*Rapports du Jury International* (Chevalier) Vol. vi., 337).

"Kaori, a gum-resin obtained from the trunks of *D. Moorei*, Lindl., *ovata*, Moore, and *lanceolata*. Yellowish or white, brittle, with a smooth shining fracture; on distillation it yields an essential oil of aromatic odour. It is soluble in alcohol and may be used as a varnish." (*Journ. de Pharm. et de Chimie*, March 1870, p. 242; *Pharm. Journ.* [3] ii. 403.)

"Several species of *Dammara* are given as the sources of kauri resin in New Caledonia. They are *D. Cornui*, Raoul, the "Metea" or stunted Kauri Pine; *D. lanceolata*, Lindl., the "Berairou," "Bora" or Red Kauri; *D. Moorei*, Lindl., or "Duou"; *D. ovata*, Moore, or "Ninourai," the White Kauri; *D. lanceolata* and *D. ovata* being the chief species." (*Pharm. Journ.* [3] xx., 402.)

I give one more quotation:—"*Kauri resin.* A report from Noumea by M. Formet speaks favourably of the use of this resin, —otherwise called Sydney gum and Caledonian balsam, as a suitable medium for the external application of antiseptics. All antiseptics can be mixed with the resin, which forms a coating over wounded surfaces. In cutaneous affections it is of great service; and also in the treatment of sprains and fractures when

the limb must be kept rigid." (*Chemist and Druggist of Australasia* p. 754, June 7th, 1890.)

Agathis robusta, Benth. and Hook. f., yield "Queensland Dammar." See Lauterer (33) for an analysis.

Araucaria Cunninghamii, Ait., "White-, Hoop-, Richmond River- or Moreton Bay-Pine."

In my paper (54), I announced that the exudation of this species was a gum-resin. I also stated, "The only previous instance I can find of arabin being found in a coniferous resin is by Dulk (Morel, [3] ix., 714), who found 0·1 per cent. in White Dammar (*Dammara orientalis*, Lamb.)

In 1893 I received from a Queensland correspondent an extract from "Procès-Verbaux" of the "Actes de la Sociéte Scientifique du Chili." Sesion jeneral del 4 de abril de 1892, Tome ii., 1 ère livraison, 1892." The extract was in Spanish, and not understanding that language I applied to the Consul General for Chili in Sydney (Capt. W. H. Eldred), who through ill health was unable to furnish me with the translation until 2nd June, 1894. I then ascertained that Prof. E. Heckel of Marseilles had announced the discovery of a gum in the exudation of the Australian *Araucaria Bidwilli* and in that of the Chilian *A. imbricata.*

I then wrote to Prof. Heckel under date 19th June, 1894, asking for further particulars, and he very kindly sent me a copy of his paper (14), published 20th August 1891, on *A. Bidwilli*, and which paper showed that arabin was present to the extent of nearly 70 per cent. in the exudation of that species, and to a less extent in the exudations of *A. Cunninghamii* and *A. Cookii.*

Further correspondence elicited the fact, that MM. Heckel and Schlagdenhauffen had in August 1887 (16) announced the discovery of arabin in the exudation of Araucaria. The matter stands thus, that Dulk, in 1878, made the original discovery, while Heckel and Schlagdenhauffen in 1887, and Maiden in 1889 made similar observations independently.

Mr. W. Bäuerlen, botanical collector, wrote to me as follows concerning the collection of the resin (gum resin) of *Araucaria Cunninghamii* on the Richmond River.

"The resin of this pine exudes plentifully, and when fresh it is much of the consistency and colour of cream, sometimes rather thinner. It seems that it takes a considerable time to harden when it becomes somewhat clear and yellow-looking.

"I am told that the Pine has another resin the existence of which is not generally known, and the resin has to be looked for *under the bark*, where it collects in hard dark lumps, which in appearance are certainly quite different from the usual resin, though both substances may after all be the same. Mr. James Black of Bexhill told me about the occurrence of this resin and showed me two pieces, one of which on asking for it he presented to me; strange to say, several people of whom I made enquiries respecting it, knew nothing of this hard dark resin. I shall of course follow the matter up and endeavour to find the resin in its natural state.

"I was told that the resin (yellow) of the White Pine is used medicinally in kidney complaints and is found very effective in stricture and retention of urine. A gentleman says he finds it gives great relief in very aggravated cases, when three or four doses are usually sufficient. He dissolves the resin in alcohol and gives from 20 to 30 drops in water as a dose."

Araucaria Bidwilli, Hook., "Bunya Bunya."

For an examination of the resin of this plant see Maiden (54). I there stated that the exudation of this pine would probably be found similar to that of *A. Cunninghamii* if collected under similar conditons.

The gum resins of *Araucarias* are also dealt with by Lauterer (33), who gives analyses of the exudations of *A. Bidwilli* and *A. Cunninghamii*. See also a special paper by Lauterer on *A. Bidwilli* (32).

Araucaria Cookii, R. Br.

Dr. Schuchardt of Görlitz informed me that he had found sugar in the resin of *Araucaria Cookii* from New Caledonia. (Lr. of 11/2/90).

Araucaria Rulei, F.v.M.

Prof. E. Heckel has recently published a research on the gum-resin of this New Caledonian species (15).

Araucaria brasiliana, A. Rich.

"The resin of *Araucaria brasiliana* exudes from the old trees, especially if the bark has been damaged by beetles, and hardens rapidly in the air. Dull white or dark brown irregular pieces, varying in size from that of a bean to that of a walnut, and elongated drops. Has a faint lustre, and a smooth waxy fracture. Smells balsamic, somewhat turpentine-like, and tastes resinous, biting and aromatic, sticks to the teeth. Heated on platinum foil it carbonises without melting completely, evolving an odour of incense. In a flame it takes fire and burns, leaving five per cent. of ash. The resin dissolves to the extent of about two thirds in water and one third in alcohol; ether and chloroform take up only traces of volatile oil, gum, and vegetable albumen, uncrystallizable sugar, and four different resins. From the mixture of resins, freed from volatile oil and substances soluble in water, cold alcohol takes up alpha, beta, and gamma resins, leaving araucaric acid undissolved. The gamma resin is precipitated from the alcoholic solution by acetate of copper, and the beta-resin from the filtrate by alcoholic neutral acetate of lead, whilst the alpha resin remains in solution." Further particulars of these bodies are given. (*Gmelin*, xviii. 19).

The analysis of the resin of the Chilian species should now be brought up to date, but is of special interest in view of the interest attaching to those from Australian *Araucarias*.

Callitris spp. "Australian Sandarac."

The clear resin of our Cypress pines (*Callitris* or *Frenela*) is a perfect substitute for the sandarac of commerce, used in varnish-making and for other purposes. What the actual demand for

this resin is is not thoroughly ascertained, and inquiries are being made at the present time concerning it.

The following are references to the literature of the subjéct:—

Maiden (50, 51). Lauterer (33). The paper of A. Balzer on "Sandarac Resin" (*Arch Pharm.*, 1896, 234, 289; *Journ. Chem. Soc.* 70, 493) is valuable. It gives a modern analysis of the sandarac of commerce, and hence, I believe, of Australian sandarac.

Callitris verrucosa, R. Br.

For an analysis of this sandarac by the Elder Exploring Expedition, see (61A.) See also p. 203 *infra* for an account of a recent and exhaustive research on *Callitris* resin.

We have so few references to fossil resins in Australia that the following notes are of special interest. Mr. H. T. Edwards, of Birnima, Monaro, informed me that in sinking a well at Bibbenluke he came across fossilised cypress pine-trées (*Callitris*) with a quantity of resin as if it had been recently exuded. The place was evidently an old lake-bed and the Pine trees had been submerged. The nearest growing Cypress Pine tree is seventeen miles distant.

I have been unable to trace the amount of reliance to be placed in the statements contained in the following note. In any case, the "amber" cannot be of the genus which yields the Baltic substance; it may perhaps be akin to the preceding fossil resin.

"A curious discovery, that of a mine of amber, has been made at Rokewood, and some men are now at work at the mine, and others prospecting for the same mineral in the vicinity. A professional mineralogist of Ballarat thus reports on the substance found :—'The resinous substance left with me for examination is undoubtedly amber, and has not previously, to my knowledge, been found in the colony; making, therefore, another addition to our colonial minerals. The colour of the said substance is brown, streaked yellowish white, transparent, conchoidal fracture, lustre waxy. Specific gravity 1·1. Acquires resinous electricity by

friction; contains empyreumatic oil and succinic acid, and corresponds in all other respects with the brown amber of Europe.'" [*Journn. Soc. Arts*, xv. 679.]

The following note relates to a fossil resin supposed to be from a tree allied to *Callitris* (*Frenela*):—

"A very interesting discovery of fossil resin has been made by Mr. Richard Daintree, of the Victoria Geological Survey, in the tertiary lignites of the Bass River, in the Western Port District. The remarkable substance was obtained at the depth of about 50ft. below the surface; the formation in which it occurs is of great extent, but not sufficiently explored at present to enable an estimate to be made of the probable quantity of resin available. Like many fossil substances of this class the resin from the Bass River is not easily dissolved in the ordinary menstrua; alcohol and ether take up a portion of it, the former giving rise to a brown colored solution, leaving the insoluble remainder in a swelled and bleached state; the latter forms a clear coloured solution, which by evaporation leaves a pure white residual resin. Turpentine does not exert any solvent power, while the essential oil from Victorian Myrtaceous trees appear to be its best solvents, as only a small insoluble portion remains after their action, consisting to a great extent af mineral impurities. This resinous body appears in small rounded masses, somewhat translucent internally, but possessed of a rough opaque covering; its colour is a pale brownish-grey, with a glassy fracture, it is very friable, and inflammable. On being heated it fuses with the disengagement of much volatile matter, causing a frothiness that does not subside for some time. It is less fragrant under these circumstances than the fossil resin of New Zealand, and the odour resembles that of sandarac, a circumstance leading to the opinion that this substance was originally the produce of a tree allied to the genus *Callitris*. It burns readily, leaving unconsumed a quantity of bright and bulky charcoal." (Selwyn and Ulrich, *Notes on the Physical Geography, etc., of Victoria*. Intercol. Exh. Essays, 1866).

Podocarpus elata, R. Br.

Is a very common tree with us, but I have found no resin upon it.

The following references are interesting :—

Podocarpus ferruginea yields a dark red coloured gum resin. (G. Bennett, *Wanderings of a Naturalist*, p. 415).

See also "Podocarpic Acid." (*Watt's Dict.* viii. [2], 1657).

Amongst the natural products collected by Dr. T. E. de Vrij, during his stay in the Isle of Java, was a crystalline resin produced from *Podocarpus cupressina* or *P. imbricata*, a tree common in the forests of Java, and known locally by its Malay name of Djamoudjou. This resin, when treated with alcohol, yields a white crystalline acid substance, which has been called Podocarpic acid. The last number of the *Journal für praktische Chimie* contains a long paper by Herr A. C. Oudeman, Junr., in which he describes the results of his studies of this acid, and of several of its salts and derivatives. (*Journ. Soc. Arts*, xxii. 864).

Note added, 24th January, 1902.

Dr. T. A. Henry has recently published "A chemical investigation of the constituents of the sandarac resins," (*Proc. Chem. Soc.*, xvii., 187). He examined the North African *Callitris quadrivalvis* and the Australian *C. verrucosa.* He finds the resins to be identical in composition and to consist of a mixture of resin acids and terpenes, separable by steam distillation. From the latter, pinene has been isolated and identified. Two resin acids have been isolated and examined,—one is named inactive pimaric acid, and for the other the name callitrolic acid has been retained.

The research was carried out in the laboratories of the Imperial Institute, London, of which Mr. Wyndham Dunstan is Director.

A Tentative Bibliography of Australian Vegetable Exudations.

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2. Bennett, (K. H.)—"On *Myoporum platycarpum*, a resin-producing tree of the interior of New South Wales." *Proc. Linn. Soc. N.S.W.*, vii., 349.

3. Blackett, (C. R.)—"Occurrence of Bassora Gum in Cycadeæ." The gums of *Macrozamia Fraseri* and *M. Miqueli* were examined. *Chem. and Drug.* (Australian Suppl.), 1882. *Pharm. Journ.* [3], xiii., 104.

4. Bolley, (P.)—"Amount of picric acid obtained from Botany resin, (*Xanthorrhœa hastilis*)." *Chem. Gaz.*, 1859, 136.

5. Brownscombe, (W. J.)—"Gummi Eucalypti Rostratæ." *Pharm. Journ.* [3] 25th March, 1899, p. 276.

6. Dampier, (W.)—"A new voyage round the world, describing particularly, the Isthmus of America, etc., etc.; New Holland, etc.; their soil, rivers, harbours, plants, fruits, animals and inhabitants." Third edition, 3 vols. (London, 1698 - 1709).

Vol. i., p. 463, Notes on "Dragon trees" (Eucalypts), exuding kino; Vol. iii., contains some plates of Australian plants.

7. Eucalyptus products. *Pharm. Journ.* [3], xvi., 898. Kinos are here referred to.

8. *Ficus.* "Native juices and Caoutchouc (India-rubber.)" *Agric. Gazette*, N.S.W., Nov. 1894, p. 759.

9. Fleury, (G.)—"*Grevillea robusta* gum resin." *Journ. Pharm.* [5], ix., 479. *Journ. Chem. Soc.*, xlviii., 238. Investigation of a gum-resin found on some trees of *Grevillea robusta*, cultivated in Algeria.

10. Flückiger, F. A.—"Neue Gummisorten Australiens." *Pharm. Post* (Wien) Nov. 1892. Discusses my notes on gums of *Mezoneuron* and *Panax*.

11. The same, "Neue Kino-Sorten in Australien." *Pharm. Post* (Wien) Dec. 1892. Gives reference to my papers on *Ce atopetalum* and *Milletia*, and discusses kinos in general.

12. Gmelin.—The Yellow Resin of Botany Bay. Gmelin's *Handbook of Chemistry*, xvii., 386, where a full bibliography of the subject is given. Resin of *Xanthorrhœa hastilis* (grass-tree gum).

13. Grimwade, (E. N.)—"A kino from *Eucalyptus maculata.*" *Pharm. Journ.* [3], xvi., 1, 102. A chemical examination.

14. Heckel, (E.)—"Sur le Bunya-Bunya (*Araucaria Bidwilli*, Hook.), son utilité et son acclimatation en Algérie et dans nos Colonies Francaises." *Revue des Sciences Nat. appliquées*, No. 16, 20th Aug., 1891.

15. The same, "Sur l' *Araucaria Rulei*, F.v.M., de la Nouvelle Calédonie ; sur la composition et l' utilisation de sa gomme résine." *Rev. des Cult. Coloniales*, 20th May, 1901, p. 289.

16. Heckel, (E.) and Schlagdenhauffen, (F.)—"Sur la secretion des *Araucaria.*" Note présentée par M. A. Chatin. *Comptes Rendus* (Botanique) Tome 105, Juillet – Dec. 1887, p. 359.

17. The same, "Sur quelques gommes d' *Acacia* (*dealbata*) et d' *Eucalyptus* (*leucoxylon* and *viminalis*)." *Le Naturaliste*, 2nd Série, No. 80, p. 151, (1st July, 1890). Contains analyses of a gum and two kinos, obtained from trees growing in the south of France.

18. Hildebrand, (K.)—Xanthorrhœa resins. *Arch. Pharm.* 1896, 234, p. 698. *Journ. Chem. Soc.*, Abstr. lxxii., 227, *cf.* Abstr. 1894, i., 47. See Tschirch and Hildebrand.

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20. Holmes, (E. M.)—"Acetic Acid in Sterculia Gum." *Pharm. Journ.* [3]. xx., 560; also Maiden, (J. H.). *Pharm. Journ.* [3], xx., 868.

21. Hopff, (Dr.)—"On Australian and Turkey Gums." *Pharm. Journ.*, vii., 588. An Acacia gum is probably referred to.

22. Hudson, (F. J.)—"Kino of *E. rostrata* as a remedy in diarrhœa." *Zeitschr., des oesterr. Apoth. Ver.*, 1883, 220.

23. Johnston, (J. F. W.)—Acaroid Resin (Botany Bay Resin, Yellow Gum). "On the Constitution of the Resins." Part ii., *Phil. Trans.* 1839, p. 292.

24. Kite, (C.)—"An account of the medicinal effects of the resin of *Acaroides resinifera* or yellow resin from Botany Bay." "In his "Essays and Observations Physiological." London, 1795.

25. Kremel, (A.)—Eucalyptus kino is dealt with amongst others. He fails to find the Kinoin of Etti, (*Amer. Journ. Pharm.* 1872, 6,000.) *Pharm. Post*, 1883, No. 11.

26. Lang, (Rev. Dr.)—Gum collecting in Australia. *Cooksland*, pp. 138-9.

27. Lauterer, (J.)—"Gums of Eucalypts and Angophoras." *Proc. Roy. Soc., Qd.*, 1891, p. 37.

28. The same—"The gums of Eucalypts and Angophoras." *Pharm. Journ. N.S.W.*, Feb. 1891, p. 45.

29. The same, "Queensland native astringent medicines, illustrated by the chemistry of the gums of Eucalypts and Angophoras." *Proc. Aust. Assoc Adv. Sci*, vi., 293 (1895).

30. The same, also *Chemist and Druggist of Australasia*, May 1895, p. 108.

31. The same, "The chemical affinities between the Rutaceæ and the Umbelliferæ." *Proc. R. S. Qd.*, xii., 72.

32. The same, "On the Resin of *Araucaria Bidwilli.*" *Proc. R.S. Qd.*, xi., 12.

33. The same, "Gums and Resins exuded by Queensland plants chemically and technologically described." From pages 35 to 80 of F. M. Bailey's Botany Bulletin No. xiii., (April 1896), "Contributions to the Queensland Flora."

34. The same, "The Resin of *Evodia alata.*" *Chem. and Drugg. of Australasia*, Nov. 1896, p. 260.

35. Ligar, (C. W.)—"Grass tree." *Trans. R.S. Vict.*, Vol. vi., 1861-4, p. 145. Grass-tree gum is incidentally dealt with.

36. Maben, (T.)—"Notes on some gum samples." *Pharm. Journ.* [3], xx., 717. Takes cognisance of Wattle Gum, p. 719.

37. Maiden, (J. H.)—"Useful Native Plants of Australia," 1889, pp. 696. Arts, Gums. Resins, Kinos.

38. The same, "On the Gum of the Leopard-tree (*Flindersia maculosa*). *Proc. Aust. Assoc. Adv. Sci.*, ii., 379.

39. The same, "Observations on the Gums yielded by two species of *Ceratopetalum.*" *Proc. Aust. Assoc. Adv. Sci.*, ii., 381.

40. The same, "On Cedar Gum (*Cedrela australis*)." *Proc. Linn. Soc., N.S.W.*, [2], iv., 1047.

41. The same, "Sterculia Gum: its similarities and dissimilarities to Tragacanth. Occurrence of Pararabin in Sterculia Gums." *Pharm. Journ.* [3] xx., 381.

42. The same; "Gums and a resin, produced by Australian Proteaceæ." *Proc. R.S., S.A.*, 1889, p. 54.

43. The same, "Macrozamia (Encephalartos) Gum, including a discussion of the question, what is Bassorin?" *Chem. and Drugg. of Australasia*, Jan., Feb., 1890.

44. The same, "The Chemistry and Commercial possibilities of Wattle Gum." *Pharm. Journ.* [3], xx., 869, 980.

45. The same, "On two unrecorded exudations from the Leguminosæ." *Proc. Linn. Soc., N.S.W.* [2]. i. A kino from the "Native Wistaria," *Milletia (Wistaria) megasperma.* ii. A gum from "The Barrister," (*Mezoneuron Scortechinii*).

46. The same, "On Panax Gum." *Proc. Linn. Soc., N.S.W.*, [2]. The following gums are described; *P. dendroides* var. *angusta*, *P. Murrayi*, and *P. elegans.*

47. The same, "On the occurrence of a Gum in *Echinocarpus (Sloanea) australis*, Benth." *Proc. Linn. Soc., N.S.W.* [2], vi., 140 - 2.

48. The same, "On Grass-tree Gum." *Proc. Linn. Soc., N.S.W.* [2], v., 429.

49. The same, "Grass-tree Gum." *Agric. Gaz. N.S.W.*, Nov. 1894.

50. The same, "Australian and Tasmanian Sandarach." *Proc. R. S. Tas.*, 1889, p. 55. Showing the identity of the resin of the Australian species of Callitris with the sandarach of commerce.

51. The same, "Australian Sandarach." *Agric. Gaz. N.S.W.*, May, 1894.

52. The same, "Spinifex Resin." *Proc. Linn. Soc. N.S.W.*, [2], iv., p. 639. A resin from North-west Australia, supposed to be obtained from *Spinifex (Triodia)* roots, and used by the blacks as cement.

53. The same, "On the Resin of *Myoporum platycarpum.*" *Journ. Chem. Soc.*, lv., 665. A preliminary chemical investigation.

54. The same, "Notes on the Resins of two Queensland species of *Araucaria.*" *Proc. R. S. Qd*, vi., Part 1, 1889. *A. Bidwilli* and *A. Cunninghamii.*

55. The same, "On the Oleo-resin of *Canarium Muelleri*, Bailey, together with notes on Manila Elemi." *Proc. R. S. Qd.*, viii., Part 3. The exudation of *C. Muelleri* is a simple oleo-resin, quite different in character to Manila Elemi, usually attributed to *C. commune.*

56. The same, "Notes on the exudations yielded by Australian species of *Pittosporum.*" *Proc. Aust. Assoc. Adv. Sci.*, iv. Principally deals with the composition of the gum-resins of *P. undulatum* and *P. bicolor.*

57. The same, "The examination of Kinos as an aid in the diagnosis of Eucalypts." Part 1: The Ruby Group. *Proc. Linn. Soc. N.S.W.*, [2], iv., p. 605. Part 2: The Gummy Group, [2], iv., p. 1277. Part 3: The Turbid Group, [2], vi., p. 389. The groups are primarily divided according to the behaviour of the kinos in water and alcohol.

58. The same, "Botany Bay or Eucalyptus Kino." *Pharm. Journ.* [3], xx., pp. 221 - 321. Comprises the following papers:— 1, Commerce and uses of Eucalyptus Kinos; 2, Collection of Eucalyptus Kinos; 3, Use of the word "gum" or "gum-tree" in Australia; 4, Classification of Eucalyptus Kinos. 5, Definition of the terms "Botany Bay Kino," or "Australia Kino," by gelatinization of tincture of kino.

59. The same, "Liquid Kino." *Proc. R. S. Vict.*, 1889, p. 82. The liquid exudation of *Angophora intermedia.*

60. The same, "Angophora Kinos." *Proc. Linn. Soc., N.S.W.*, [2], v. Including analysis of the solid kinos of *A. intermedia* and *A. lanceolata.*

61. The same, "The Murray Red-Gum (*Eucalyptus rostrata,* Schlecht), and its Kino." *Amer. Journ. Phar.*, lxix., 1 (Jan. 1897).

61A. The same, "Report on the Vegetable Exudations collected by the Elder Exploring Expedition." *Proc. R. S. S.A.*, xvi., 1.

62. The same, "Notes on some vegetable exudations." Appendix to the *Report of the Horn Expedition to Central Australia.* Part 3, Geology and Botany, March 1896.

63. Maiden (J. H.), and Smith (H. G.)—"A contribution to the chemistry of Australian Myrtaceous Kinos." *Proc. R. S. N.S.W.*, xxix., p. 30.

63A. The same, "Contributions to a knowledge of Australian Vegetable Exudations, Part i.." *Proc. Roy. Soc., N.S.W.*, xxix.

64. Maisch, (J. M.)—"Notes on Xanthorrhoea Resins." *Amer. Journ. Pharm.*, May 1881. *Pharm. Journ.* [3], xi., 1005.

65. Mills, (E. J.) and Muter, (J.)—"On bromine absorptions." *Journ. Soc. Chem. Ind.*, iv., 96. Resins of various species of *Xanthorrhœa* are experimented with amongst others.

66. Morel, (J.)—"Resin of *Callitris Priesii.*" *Pharm. Journ.* [3], viii., 1025. Müller, (H.)—[See "Rue (De La) and Müller."] Muter, (J.)—[See "Mills and Muter."]

67. Palladino, (P.)—"Soluble Gums." *Bull. Soc. Chem.* [3], ix., 578. *Journ. Chem. Soc.*, lxvi., 6, (1894). Includes notes on Australian gums.

68. Phillip, (A.)—"The voyage of Governor Phillip to Botany Bay etc." (4° London, 1789). Account of the "red and yellow gum-trees (*Eucalyptus* and *Xanthorrhœa hastilis*), pages 59 and 60; Dr. Blane's account of the good effects of the yellow gum, p. 294.

69. Redwood, (T.)—"On the gelatinization of tincture of Kino." *Pharm. Journ.*, i., 399. Eucalyptus kino is referred to in general terms.

70. Rennie, (E. H.)—"On New Zealand Kauri Gum." *Journ. Chem. Soc.*, xxxix., 240, (May 1881)

71. Rennie, (E. H.) and Goyder, (G.)—"The resins of *Ficus rubiginosa* and *F. macrophylla* (Preliminary notice)." *Journ. Chem. Soc.*, lxi., 916.

72. Rideal, (S.) and Youle, (W. E.)—"Gum Arabic and its modern substitutes." *Journ. Soc. Chem. Ind.*, x., 610. Takes cognizance of the Wattle Gums.

73. Rue, (W. De La) and Müller, (H.)—"On the resin of *Ficus rubiginosa*, and a new homologue of Benzylic Alcohol." *Phil. Trans*, Vol. 150, 43 (1860). *Journ. Chem. Soc.*, xv., 62, (1862). *Watt's Dict.*, ii., 646, and v., 645. (Sycocerylic acid, etc.) see *Gmelin*, xvii., 43, for fuller bibliography. An exhaustive chemical research on a sample of dried latex from the Manning River. A resin, called by the authors Sycoretin, is found in it, and this resin and its derivatives are described at length.

74. Schimmel & Co. (Leipzig).—"Oil from *Xanthorrhœa hastilis*." *Reports of Oct.*, 1897, p. 60.

Schlagdenhauffen (F.)—See "Heckel and Schlagdenhauffen."

75. Simmonds, (P. L.)—"The gums and resins of commerce." *Journ. Soc. Arts*, iv., 18. A *Xanthorrhœa* resin of Western Australia is dealt with.

76. The same, "The resins, gums, and gum-resins of Victoria." *The Technologist*, v., 227. Compiled from the Victorian *Catalogue of Exhibits*, Dublin Exhibition, 1865. [See p. 9.]

77. The same, "Botany Bay or Grass-tree Gum." *The Technologist*, vi., p. 523. *Pharm. Journ.* [2], viii., p. 78. Deals chiefly with the production of illuminating gas from a Western Australian species.

78. Smith (H. G.)—"On Aromadendrin or Aromadendric Acid from the Turbid group of Eucalyptus Kinos." *Journ. R.S. N.S.W.*, p. 135 (1896).

79. The same, "The dyeing properties of Aromadendrin and of the Tannins of Eucalyptus Kinos." *Journ. Chem. Soc. Ind.*, xv., (1896). See also Maiden and Smith.

80. Stenhouse (J.)—"Resin of *Xanthorrhœa*." *Tas. Journ.*, Vol. ii., 1846, p. 360. Abstract of following observations on the resin of the *Xanthorrhœa hastilis*, or Yellow Gum Resin of New Holland. *Chem. Soc. Mem*, iii., (1845 - 8), pp. 10 - 12. *Phil. Mag.*, xxviii., p. 440, June 1846. *Pharm. Journ.*, vi., 88. The first thorough chemical examination of this resin, and the basis of subsequent statements concerning it.

81. Sutherland (J.)—"On the medicinal properties of the Red Gum of Australia." *The Technologist*, iii., p. 69. A brief essay on the chemical behaviour and therapeutic effects of the kino of *Eucalyptus rostrata*.

82. Thomson (T.)—"Of Botany Bay Resin." *Chemistry of Organic Bodies*. Vegetables (1838), p. 532. Quotes Duncan's *New Dispensary*, p. 60, and Lichtenstein, *Crell's Journ.*, 1799, ii., p. 242.

83. Tschirch and Hildebrand—"Grass-tree Gums." *Pharm. Journ.*, May 1st, 1897, p. 370.

84. Trommsdorff—"Volatile Oil of Botany Bay Resin (*Xanthorrhœa hastilis*)." *Taschenberg*, 1826, p. 9. *Gmelin*, xiv., 362.

85. White (J.)—"Journal of a Voyage to New South Wales, with sixty five plates of nondescript animals, etc., curious cones of trees, and other natural productions." 4to., London, 1790. Kino for medicinal use, p. 178; Yellow resin *(Xanthorrhœa hastilis)* p. 179; Peppermint-tree *(Eucalyptus piperita)*, with figure, p. 226; the "Red Gum" tree *(Eucalyptus resinifera)*, with figure, and notes on its medicinal value, p. 231; the "Yellow Resin" tree *(Xanthorrhœa)*, with description and account of its properties, p. 235; figure of part of caudex of *Xanthorrhœa* cemented with resin, p. 249.

86. Wiesner (T.)—"Eucalyptus Gum." *Pharm. Journ.* [3], ii., p. 102. *Zeitscher. d. Allg. Oest. Apotheker. Vereines.* Contains notes on a number of kinos.

Youle (W. E.)—See "Rideal and Youl."

87. Zeyer (E.)—"Resin in bark of *Atherosperma moschata.*" *Pharm. Viertelj*, x., p. 517. Abstr. in Gmelin's *Handbook*.

Addendum to *Ficus*, p. 193. In response to enquires, I take the opportunity of stating that, in my opinion, *Ficus elastica*, Roxb., is the best India-rubber tree for commercial cultivation in New South Wales.

ROCK-HOLES USED BY THE ABORIGINES FOR WARMING WATER.

By R. H. MATHEWS, L.S., Corres. Memb. Anthrop. Soc., Washington, U.S.A.

[*Read before the Royal Society of N. S. Wales, December 4, 1901.*]

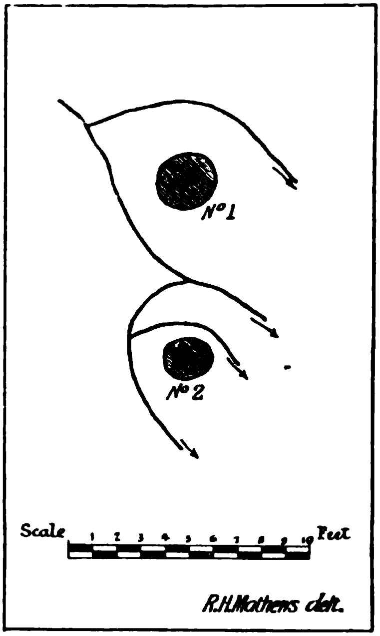
IN a communication to the Anthropological Institute of Great Britain on this subject in 1896,[1] I described a number of holes in rocks which had apparently been used by the aborigines in cooking their food. The mass of sandstone containing the holes therein described is situated within Portion No. 1139, of 24½ acres in the parish of Manly Cove, county of Cumberland.

About thirty miles southerly from the ovens above referred to, I discovered two similar "pot holes" in the surface of a large table of Hawkesbury Sandstone on the side of a gully or watercourse, at the head of Dead-man's Creek, within Portion No. 19, of 960 acres, in the parish of Eckersley, county of Cumberland, and about two miles northerly from the Woronora River.

During wet seasons a small stream of water runs over the large rock on which these pot-holes are found, but in a dry time the water merely trickles along the lowest parts of it. The black lines shown on the diagram, represent grooves cut into the rock surface, apparently for the purpose of conducting this trickling stream of water past the holes or ovens marked No. 1 and No. 2, the water flowing in the direction of the arrows. (See diagram.) Unless the natives had intended to use the pot-holes for some purpose, it is unlikely that they would have cut these grooves, which must have been a work of much labour, considering their rude stone tools.

The pot-hole marked "No. 1," is a little over two feet in diameter, and about a foot deep. "No. 2" is one foot nine inches

[1] Journ. Anthrop. Inst., xxv., 255 - 259, plate 17.



in diameter, and its depth eighteen inches. A few yards down the bed of this gully is a small waterhole, which appears to contain a permanent supply of water, being fed by a small spring oozing out of the bank. About one hundred and fifty yards westerly from these ovens is a piece of level ground, surrounded by ridges which shelter it from storms, and which would have been a very eligible site for a camping ground for the aborigines in olden times. The soil in this locality is sandy, and therefore not so suitable for making holes in it for cooking game as if it were clayey, which latter would hold the heat better. This would be an additional inducement for the natives to select holes in rocks for this purpose.

Close to the pot-holes, or ovens, are several figures carved upon the surface of the same large rock, one of which represents the forepart of a kangaroo or wallaby, the remainder of the animal's outline having weathered away beyond restoration. The other figures consist of grotesque forms more or less human in shape, one of which appears to have been intended for some mythologic creature, the type of which does not exist in nature. The carvings are shown as Figs. 19, 20, 21, and 30 of Plate ii., in a paper contributed by me to the Anthropological Society at Washington in 1895.[1]

[1] American Anthropologist, VIII., pp. 268 – 278.

Scattered here and there over the rock surface are a number of hollows worn by the aborigines in sharpening their stone tomahawks. I counted one hundred and thirteen of these grinding places within a radius of about thirty yards from where the ovens and carvings above described are situated. The length of these hollows or grinding places vary from about a foot to eighteen inches. For descriptions and drawings of similar native grinding places see my paper on "Some Stone Implements used by the Aborigines of N. S Wales."[1]

Some of the old blackfellows belonging to the Shoalhaven River and other parts of the south-east coast of New South Wales, have told me that in the winter time, when the water was very cold, they used to warm it by means of hot stones. Water was brought in a native vessel made of bark or wood, and one or more stones were heated in the fire and lifted into the water with a forked stick, to take the chill off it, in order that the natives could drink it with comfort. My informants also stated that wild honey was sometimes added to the water to make a palatable and nutritious drink.

These statements show that the natives were acquainted with warm water, and the theory may be advanced with some reason, that instead of carrying water in a vessel, as stated, if a suitable pot-hole could be found in the rock contiguous to the water, into which the latter could be drained, heated stones could be thrown into it to warm the liquid for the purpose of drinking. This method of warming water was the one in use before the white people settled in the country; since the advent of the latter the natives have used European vessels for this purpose.

The following is the copy of a letter on this subject received by me in 1897 from the veteran explorer, the Hon. A. C. Gregory, C.M.G.: "In reply to your enquiry relative to the custom among the natives in north Australia of boiling fish by immersing heated stones in

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[1] Journ. Roy. Soc., N. S. Wales, XXVIII., 301 – 305, Plate 43.

water, I beg to state that Mr. Baines,[1] the artist of the expedition under my command in 1856, told me that he had seen the aborigines boiling fish by putting heated stones into water collected in small holes in the clay, on the banks of the Victoria River, in the Northern Territory. Mr. Baines was a very careful observer of aboriginal customs, and had been some years in South Africa, where he had visited the ancient gold mines of the Transvaal, and noted the evidence of their antiquity."

I shall be pleased if any of the readers of this article can supply some reliable information on this part of the subject, because it is of considerable importance, the general belief being that the aborigines of Australia were unacquainted with the use of hot water in preparing their food.

It has been reported by a number of observers, including myself, that the aborigines over an extensive geographic area, when cooking game in holes in the ground, poured small quantities of water upon the hot clay and stones forming the floor of the oven, for the purpose of creating steam to assist the cooking process. This may be regarded as a step in the direction of acquiring a knowledge of the use of hot water in cooking game and vegetable products.

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[1] Mr. Baines also communicated this information to others, in a less definite form. See "Aborigines of Victoria," by R. B. Smyth, Vol. i., p. 37. Knowing that Mr. Baines had been out with Mr. Gregory, I wrote to the latter gentleman to obtain fuller particulars, with the above result.

SOME ABORIGINAL TRIBES OF WESTERN AUSTRALIA.

By R. H. MATHEWS, L.S., Memb. Assoc. Étranger Soc. d'Anthrop. de Paris,

[*Read before the Royal Society of N. S. Wales, December 4, 1901.*]

IN this short article it is intended to show the rules of marriage and descent, a few of the totems, a brief vocabulary of the language, and some of the customs of certain aboriginal tribes inhabiting an immense extent of country on the sources of the Fitzroy, Margaret, and Ord Rivers, in Western Australia.

The people of each tribe are classified into eight sections, which intermarry one with the other in conformity with fixed laws, which will be understood in studying the subjoined table and its explanatory letter-press. The people composing a section do not collect into certain localities by themselves, but are mixed indiscriminately with all the other sections. Some of the principal tribes bearing the eight section names given in the table are the Kisha, Gunyan, Lungar, Nining, Jarrau and Walmaharri.

Table No. 1.

Phatry.	Parents.		Offspring.	
	Father.	Mother.	Son.	Daughter.
A.	Changura	Nungala	Chabalyi	Nauajerri
	Chauan	Nauuru	Chauarding	Nabungarti
	Chagara	Nauajerri	Chuaru	Nauuru
	Chambin	Nabungarti	Chungala	Nungala
B.	Chungala	Nangili	Chambin	Nambin
	Chuaru	Nauana	Chagara	Nagara
	Chauarding	Nambin	Chauan	Nauana
	Chabalyi	Nagara	Changura	Nangili

A Changura man takes a Nungala woman, who is his tabular or regular spouse; but he has the alternative of marrying a Nauuru

maiden instead: or, he can, in certain cases only, choose a Nauana as his wife.

Similarly, a man of the Chauan section, whose regular or tabular wife is Nauuru, can marry Nungala as an alternative; and in rare cases, may take a Nangili spouse.

In examining the statements contained in the last two paragraphs in connection with Table No. 1, it will be seen that Changura and Chauan may exercise their choice over the same two sections of women; and moreover, they can exchange their sisters with each other as wives. In other words, Changura and Chauan can mutually exchange their wives and sisters. These remarks apply to each of the other pairs of sections in the 'Father' column of the table, in both phratries.

The following are a few of the totems belonging to each section, male and female:—Changura, dark honey. Nangili, rat. Chauan, wallaby, wattle tree. Nauana, yellow honey, large kangaroo (female). Chagara, bandicoot, large kangaroo (male). Nagara, wild honey. Chambin, opossum, black bream, native-cat. Nambin, black-headed snake. Chungala, black-swan, iguana. Nungala, cockatoo, bony bream, native companion. Chuaru, moon, wallaroo, cat-fish, jew-fish, alligator, native cat, flying-fox, iguana. Nauuru, kangaroo (female), black-duck, crow. Chauarding, eagle-hawk, crane, shag, kangaroo (male), brown snake, spinifex. Nabungarti, emu, large kangaroo (male). Chabalyi, star-fish, dingo. Nauajerri, sun, turkey, all ducks not mentioned above.

These natives have names for the eight points of the compass, and these points are so familiarly fixed in their minds that in directing another person where to find anything, they call out the compass point in the most natural manner. The following are the native names of the points, commencing at the north:—north, kainira; north-east, kaira; east, karnira; south-east, kara; south, golanira; south-west, golarra; west, kalanira; north-west, kalara. Up any creek or river is known as kangara, whilst down the stream is kanimburra.

A legend is current amongst these blacks that a supernatural monster in serpent form made all the rivers as he travelled inland from the sea, which is his home. Once he camped for a long time at the lake into which Sturt Creek empties, and it is owing to his urine that the water there is salt. The saltness of other lakes in that part of the country is ascribed to the same cause. This creature is known as Wonnaira in some districts and as Ranbul in others.

Mr. N. H. Stretch, a long resident in Western Australia, has under my directions, collected the Nining equivalents of the following phrases :—The man and his wife—Mauan umbir. The sister and her brother—Kaulu naje. I saw the brother of my friend—Chalache ingo nia nia naje. My wife saw her brother—Umbir anninga nia nia najengo. I gave the fruit of the tree to my daughter—Mungari ana yungo kutu bununga. The dog will eat some of the opossum—Gunyar wonnan kiri. You have taken the skin of the big kangaroo—Uto manning uro nyundo. I am eating a yam—Mungari unnung unnungo. You have eaten the porcupine—Nyundo unning unningo bugauru. We will eat the black duck—Alliba unnung unnungo guraba. I want these men to carry water from the creek to our camp—Ngappa mundellula kilyila moraura kangalu. Eat some of this kangaroo—Unjalu jache yunganing. I should like to give the bandicoot to our children—Ane yungo yutobru allinga jinga.

The foregoing phrases were taken down carefully by my friend, who is a very reliable observer, but as he did not sufficiently know the grammar of the language there are some manifest defects. The expressions are, however, of value, and contain several root words of very wide prevalence in Australian speech.

Nouns are declined for number and case by the addition of suffixes. The declension of adjectives is similar to that of the qualified nouns. Verbs and pronouns are inflected in an exhaustive manner, and are subject to numerous modifications. Prepositions and adverbs have their places in the language.

On the Lennard and Lower Fitzroy Rivers, on Jurgurra Creek, and thence along the coast to Broome, Condon and Roebourne are a number of tribes possessing an organisation with the following four section names:—

Table No. 2.

Phatry.	Father.	Mother.	Offspring.
A.	Kaiamba	Parajerri	Parungo
	Panaka	Parungo	Parajerri
B.	Parajerri	Kaiamba	Panaka
	Parungo	Panaka	Kaiamba

Among the totems of Kaiamba and Panaka are the opossum and bush-rat, whilst Parajerri and Parungo have the storm-bird and shark.

A Parajerri woman is the regularly appointed spouse of Kaiamba but he can occasionally marry a Parungo belonging to a distant tribe where there is no blood relationship. Panaka can, under like circumstances, take a Parajerri as his conjugal mate, although Parungo is his regular wife. The same rule applies to the men of the two sections in Phratry B.

It is important as well as interesting to show the equivalence of the four sectional divisions in Table No. 2 to the eight divisions in Table No. 1. The section name Kaiamba is equivalent to the two sections Changura and Chauan in Table No. 1; Panaka to Chagara and Chambin; Parajerri to Chungala and Chuara; and Parungo corresponds to Chauarding and Chabalyi.

Circumcision and cutting open the male urethra are in vogue in all the tribes treated of in this paper At their ceremonial and magical dances they use the *mirralu*, a flat thin board varying in length from about four feet to twelve feet or more, from three to six inches wide, and ornamented by carving on both sides.

VOCABULARY.

The following is a short vocabulary of the Kisha dialect, Hall's Creek, Western Australia. The English words are in the same order as those in Mr. E. M. Curr's vocabularies, for the purpose of facilitating comparison.

Kangaroo, gieri
Opossum, nunguin
Tame dog, chula
Wild dog, maringu
Emu, narabarel
Black duck, juelul
White cockatoo, labain
Crow, wongunnel
Egg, gumbilyul
Foot-mark, jumbilla
Fish, gunderri
Lobster, mulgural
Mosquito, gulingi
Fly, bunal
Snake, ngamari
The blacks, mullaeauing
A blackfellow, geraugen
A blackwoman, namininni
Nose, manalge
Hand, murla
Two blacks, bungarri
Three blacks, murguin
One, nundi
Two, buba
Three, gunji
Four, wularri
Father, ngabwain
Mother, gural
Elder sister, nagil
Elder brother, nagain
Young man, nakinji
Old man, kangain
Old moman, nallina
A baby, nalinunning
Children, woninneking

Head, tumwing
Eye, mulji
Ear, garding
Month, thurding
Teeth, mindiwing
Hair of head, gambaring
Beard, thauring
Thunder, malngiring
Grass, mungaring
Tongue, tullaling
Stomach, jarring
Breasts, female, gumwing
Thigh, ballaring
Foot, jambaling
Bone, guji
Blood, gulji
Skin, wongari
Fat, mulinguain
Excrement, garning
War-spear, kallimbing
Womera, ngaualil
Shield, guarri
Tomahawk, wumal
Sun, bandal
Moon, carnging
Star, wordal
Light, dili
Dark, maubain
Cold, warngum
Heat, pudburra
Day, dirrundun
Night, munbain
Fire, marning or thumbain
Water, kurning
Smoke, wongain

Ground, ballowing
Wind, gurngulling
Rain, jardain
Demon, juaring
Boomerang, karribil
Rocky hill, ngari
Wood, marning
Camp, tawm
Yes, uai
No, ngoan
I, mariji
You, marribi
Bark, jerrarungburra
Bad, gulguring
Sweet, nauering
Food, maii
Hungry, gurinyinya
Thirsty, thuandu
Eat, jangary
Sleep, bugaringa
Drink, wulagara
Walk, mariarga
See, thoma
Sit, roraringa
Yesterday, gaginberri

To-day, } muggin muggin
To-morrow, } muggin muggin
Where are the blacks? kishua burrinbai jarlimbai
I don't know, ngoanberri jarlimbai
Plenty, malgum
Big, nering
Little, winnuwaring
Dead, brauar
By and bye, margi margi
Come on, maribin
Milk, gumwing
Eaglehawk, gunberring
Wild Turkey, julgul
Wife, wombernukkel
Copulation, } ballimberaid
Sodomy, } ballimberaid
Masturbation, thurinbumarling
Penis, nauing
Woman's pudendœ, ginti
Urine, burriwonji
Circumcision, wongaring
Subincision, jabuting
Similar operation on women, tulbaugamburraunain

PROJECTS FOR WATER CONSERVATION, IRRIGATION AND DRAINAGE IN NEW SOUTH WALES.

By H. G. McKINNEY, M.E., M. Inst. C.E.

[*Read before the Royal Society of N. S. Wales, December 4, 1901.*]

Physical conditions necessary for extensive irrigation.—As a rule, when we find mountains of sufficient height to constitute the source of large permanent rivers, and when these rivers flow for a considerable part of their course through alluvial plains, we may conclude that the conditions favour irrigation on an extensive scale. Broadly speaking these are the conditions which have been made so much of in Upper India and in Egypt, as also the conditions under which extensive areas have been brought into cultivation in the Western States of America, and under which Lombardy has long been the garden of Europe. They are the conditions too under which in a more or less rough and unscientific manner great results have been accomplished in China, and to which we may look for great developments in the plains of South America.

Best conditions obtainable.—These conditions naturally vary greatly in different countries and in different parts of the same country. When perpetual snows on the higher parts of the catchment area of a river maintain a high supply of water during the spring and summer, when the supply is maintained up to the required standard by rainfall in winter, and when the water carries with it a fertilising deposit, these conditions combined may be considered the most advantageous which can be looked for. The actual conditions existing in Egypt are probably the closest approach on a large scale to this ideal. Among the great rivers of the world whose waters are being used or can be used extensively for irrigation, the Nile on two important points stands pre-eminent. Lakes Victoria and Albert together with the

immense swamps south of Fashoda and Lake Dembea in Abyssinia, are natural storage reservoirs which moderate the height of floods and maintain the regularity of the supply in the river; while the volcanic soils from Abyssinia, the organic matter from the swamps in what is known as the Sadd Region, and the lime brought down by one of the southern tributaries, combine to form a sediment which could scarcely be surpassed in fertilising properties. The rivers of Upper India are in flood throughout the summer months owing to the great areas of snow-covered mountains near their sources, but their waters have no such fertilising properties as those of the Nile. As the natural result of this, the alluvial deposits of Egypt are incomparably more fertile than those of Upper India.

Extensive natural irrigation.—Before leaving the general conditions under which irrigation works on an extensive scale are practicable, it is necessary to refer to a variation of these conditions under which irrigation takes place, either naturally or with comparatively little assistance to the operation of nature. It may be stated as a general rule, that the formation of deltas and alluvial plains is due to successive inundations extending over long periods of time. The conditions indicated by such plains are best understood if we look back in imagination to the time when the river to which these plains owe their existence flowed in a well-defined valley, and with tributary streams flowing in through ravines and minor valleys along its course. The silt brought down from the upper parts of the catchment area must have been deposited in layers which gradually obliterated the outlines of the lower part of the valley, covering dale and hill alike under a continuous sheet of alluvium through which the waters of the river had to make their way in ever changing channels and under ever-increasing difficulties. Where the course of a river extends for a long distance under such conditions and with a low rate of fall, the river channel contracts till it becomes unequal to the task of carrying on a high supply. Hence there is an increasing tendency to the spread of the flood waters and to

the formation of outflow channels, with the ultimate prospect of the complete disappearance of the river and the dispersal of its waters in numberless small channels or in marshes. If such a river be fed to any considerable extent by melting snow, there will be natural irrigation on a more or less extensive scale at the most suitable period of the year. It is to such a concurrence of conditions that the inundation canals on the lower parts of the rivers of the Punjab owe their great value; and somewhat similar conditions operate to the great benefit of large areas of country on the borders of Afghanistan and Persia.

General conditions in New South Wales.—In considering the conditions of New South Wales with reference to the general principles stated above, we find at the outset that it possesses practically only one range of mountains which ensures the provision of water in sufficient quantities for irrigation on even a moderately large scale. This is the Dividing Range, which extends through the State approximately parallel to the coast line at a mean distance inland of about seventy miles. As the summit of this range varies generally from 3,000 to 5,000 feet above sea level, it is obvious that there must be a rapid rate of fall and consequently a high velocity in the coastal rivers. Notwithstanding the resistance of the sea water, a large proportion of the silt is carried into the ocean where its deposit to form deltas at the mouths of the rivers is effectually prevented by the coastal currents. Hence we find that our coastal rivers have no deltas in the ordinary sense of the term; though on the lower parts of their courses there are considerable areas of river deposit. These areas of alluvial land are more or less interspersed with marshes and lagoons, and, owing to the more violent and spasmodic action under which the deposits took place, they lack the regularity in slope and outline which is a general characteristic of the alluvial plains in the Central and Western Divisions of the State. Hence even if the conditions of the climate necessitated or warranted extensive irrigation works on the coastal rivers, the physical conditions are unfavourable. Fortunately the rainfall is fairly

satisfactory, so that although irrigation would in many cases be a useful adjunct, it cannot be regarded as a necessity. In fact owing to the amount of the rainfall to the flow and percolation from adjacent hills, and to the small height of the land above the rivers and above sea level, drainage, as a general rule, is a much more important question than irrigation throughout the coastal district.

Drainage more important than irrigation in the coast district.—There are points in connection with the conditions here which remind the present writer of extensive drainage works on which he was engaged many years ago near the lower parts of the Eastern Jumna Canal. In that case there were extensive areas of low-lying land which had become water-logged through proximity to the canal and its distributaries. Although it was necessary to drain these marsh lands, and although the average rainfall in the district in which they were situated was fully 30 inches, the irrigation from the Eastern Jumna Canal then gave, and it is believed, still gives, a larger percentage return than any other large irrigation canal in Upper India. Attention is called to this by way of illustration of the fact that the presence of swamps which require drainage works to carry off surplus water must not be taken as an indication that irrigation would not be remunerative in their neighbourhood. As a matter of fact there are many places along the coastal district in which irrigation can be successfully practised. This is no mere matter of opinion, as the writer saw a number of instances of the fact whilst acting as Judge of Irrigated Farms and Orchards for the Department of Agriculture.

Tablelands and western valleys of the Dividing Range.—Leaving the coastal district and coming to the table lands and the defined valleys on the west side of the Dividing Range, we are still on an extensive belt of land throughout which there is a fair average rainfall, and in which irrigation can scarcely be regarded as a necessity. There are, however, many places here in which water can be utilized on the land by gravitation, and there are also many places in the valleys both of the main rivers and their tributaries where ideal conditions exist both, as regards the nature

of the soil and the excellence of the natural underground drainage. Owing to the comparatively favourable conditions as to rainfall and to the sparseness of settlement, it is not surprising that little has yet been done in regard to irrigation between the summit of the Dividing Range and the margin of the great plains of the Central Division. It may be mentioned, however, that there are cases in which it has been practised in this locality with satisfactory results. In the belt of country referred to, the best instance of the use of water on the land by gravitation which came under the notice of the writer was at Tumut, and the best instance of irrigation by pumping was on the river Namoi above Gunnedah. Along the courses of nearly all the rivers which flow westward there are limited areas of valleys and flats which are eminently suited for irrigation. This remark has special application to the Lachlan, the Namoi, and the Gwydir.

The great plains of the Central and Western Divisions.—The great field for irrigation is on that immense area of alluvial deposits which cover the greater part of the centre of the State. Any one who studies the question of the practicability of conducting the waters of our western rivers through these plains cannot fail to notice at the outset the contrast between the great area and depth of the alluvium on the one hand, and on the other the fourth rate magnitude of the mountains from which it came. It would be an interesting exercise for a student of geology to work out theories regarding the height which the mountains reached before the formation of the plains began. Whatever the conclusion arrived at might be, one thing is certain in connection with it, and that is that there is abundance of alluvium to account for the former existence of mountains of great magnitude. In short, the physical features of the country are marred by old age and decrepitude; but the polished grooves on the granite of Mount Kosciusko show that there was a time of perpetual snows and glaciers, while according to some authorities, the remains of the Diprotodon discovered in places where such animals could not now exist, indicate a period of abundant rainfall such as might be expected in a country rich in mountains.

The Murray and Murrumbidgee our only valuable rivers for Irrigation.—As a natural result of the absence of perpetual snows and of mountains of any great height, our rivers are of comparatively small discharge and uncertain flow. Of the rivers which flow westward from the Dividing Range, only the Murray and the Murrumbidgee possess sufficient regularity of flow to make them valuable as sources of supply for large irrigation canals. In both cases the regularity is due chiefly to the extent of mountainous country on which snow accumulates in considerable quantity in the winter months. In the case of the Murray, the greater height of the mountains and the extensive deposits of snow ensure a large supply of water in the spring and early summer months, and this high supply frequently continues till the middle of January. Large areas of disintegrated granite and of open soil on the mountain sides, and the porous deposits of the river flats, render a slowly percolating supply to the river and contribute materially to the maintenance of a comparatively equable flow. The superiority of the catchment of the Murray above Albury to that of the Murrumbidgee above Wagga Wagga is evidenced by the fact that while the area in the former case is only about half that in the latter, the average minimum discharge during a period of seventeen years was about 1,400 cubic feet per second in the case of the Murray, as compared with about 950 cubic feet per second in the case of the Murrumbidgee. It may be here remarked that the Indian Irrigation Department introduced a word to express the unit of measurement of water, namely "cusec," which is simply abbreviated from "cubic feet per second," and as it is a recognised term and is much more convenient, it will be used wherever necessary in this paper.

First proposals for utilising the waters of the Murray in New South Wales.—Early in 1885, it became the duty of the present writer to inspect the river Murray with a view to suggesting what could be done towards utilising its waters. Information as to its discharge and regarding the relative levels of the river and the plains adjacent was meagre and fragmentary, but all that was

obtainable was made use of. The result of that inspection was the conclusion that the best place for diverting a supply of water for irrigation and other purposes, throughout the plains between the Murray and Edward Rivers on the south, and the Billabong Creek on the north, is at Bungowannah, about six miles down stream from Albury. The second important conclusion arrived at was that great benefit would be conferred by increasing the flow in Tuppal Creek and the Edward River, and that this was quite practicable. Events have moved slowly in regard to these questions, but after the lapse of several years, sanction was obtained to carry out the necessary surveys. These entirely corroborated the conclusions arrived at. In 1896 the whole question of Water Conservation and Irrigation in New South Wales was referred to Colonel Home, R.E., C.S.I., and in October, 1897, or twelve and a half years after the first report on the Murray River, he stated his concurrence in the opinion that the site of the proposed off-take at Bungowannah is the best, if not the only suitable site for diverting water through the plains extending along the north side of the Murray and Edward Rivers. Colonel Home further stated his opinion that the question of constructing a canal from the Murray below Tocumwal—that is at about the point of natural outflow to Tuppal Creek—was one well worthy of further consideration.

The river Murray canal project.—The maximum quantity of water which the writer proposed to divert from the river Murray at Bungowannah was 1,500 cusecs, but Colonel Home considered that it would be more prudent to limit the maximum to 1,300 cusecs. As regards the general design and scope of the scheme, no modification was recommended. There is, in fact, only one course which can be adopted without causing a heavy additional outlay, so far as the first twenty miles at least, of the main canal are concerned. It must follow the margin of the low ground till it reaches Howlong, and from there it must follow the depression known as Twelve Mile Creek till the depth of excavation becomes moderate. Even by adopting this line, it is impossible to avoid

deep cutting, extending through a length of ten or twelve miles. This is the most costly part of the scheme; and, as already stated, it cannot be avoided. After the canal emerges from the deep cutting, the rate of fall in the country as far as the neighbourhood of Berrigan is much greater than would be safe for the channel. On this account it will be necessary to construct a series of drops, which will necessarily involve considerable outlay; but these may prove most useful in supplying power. There will be at least six of these drops, and if it be assumed that only 500 cusecs will be used for power at each drop, and that the effective fall in each case will be six feet, which will be very nearly the actual amount, the power available will be equal to more than two thousand horse power, or to about three hundred and forty horse power at each drop. The land in the neighbourhood of these drops is to a large extent excellent for wheat growing—in fact the district around is one of the best in New South Wales for this purpose. The place where drops will chiefly be required is in the length of thirty miles ending at Berrigan.

Particulars regarding the proposed Murray River canal.—It may here be mentioned that the rate of fall proposed for the main canal was nine inches per mile, and this was approved by Colonel Home. To carry the proposed supply with this rate of fall and with side slopes of $1\frac{1}{2}$ to 1, and a depth of full supply of 7 feet, a bed width of about 68 feet will be required. The mean velocity will be nearly 2·4 feet per second. These conditions can be very little departed from, but it is possible that when the full details have been obtained it may be permissible to increase the depth of full supply to $7\frac{1}{2}$ feet or even 8 feet. That would have the advantage of allowing a decrease of the cross section of the canal.

Irregularity of country from Mulwala to Berrigan.—Before leaving the subject of the main canal there is a point which deserves special mention. When the river Murray and the plains extending to the Billabong Creek, were first inspected in 1885 with reference to the question of constructing canals, it was

observed that there were some granite outcrops in the part of the district lying to the northward of a line joining Mulwala and Tocumwal. Although to the eye there seemed to be no extensive elevation of the land, it was considered probable that the levels would show local rises near these outcrops. The effect of the presence of these outcrops proved much greater than was anticipated. The levels show that the contours are materially affected throughout an area equal to a circle of about eighteen miles in diameter. Within this area the land in one place reaches a height of 167 feet above the adjacent plains, and in another a height of 150 feet. This area approximates roughly to circular in form, but a line from Berrigan to Mulwala would pass through its greatest length which is about twenty miles.

General uniformity of the district.—Leaving out this portion of the district, the levels show that from about the western boundary of the County of Hume, the contours are very regular and show a gradually diminishing fall in a westerly direction; but in some places, and particularly when approaching Jerilderie, the direction of maximum fall is north-westerly. So far as the levels are concerned, it is quite practicable to take off branch canals to Tocumwal and Deniliquin on the south side and to Urana, Jerilderie, Conargo, and Wangonilla on the north side. The delivery of the water on the land by gravitation could begin about forty miles above Berrigan. From that town onward it can be delivered throughout the entire district.

The importance of the project not realised.—Although many of the residents of the district which would be directly benefited by the proposed Murray River Canal naturally take great interest in the subject, few, if any, of them even approximately realize the magnitude and value of the project. It may perhaps put the question in a clearer light if its capabilities be compared with some existing arrangements for supplying water.

Illustration of the value of the project.—It is well known that in Riverina as well as in other parts of the State, pumping engines

are frequently used to raise water for irrigation and for filling tanks. These pumps vary greatly in lifting capacity, and the conditions as to the amount of lift, the cost of erection, and other matters affecting the total cost of delivering the water also vary through a wide range. Under these circumstances it is not possible to arrive at anything more than a rough approximation of the average cost at which the water is obtained. The difficulty in arriving at a conclusion on this question is much increased by the very intermittent manner in which pumping plants on pastoral and agricultural estates are worked. Assuming that a pumping plant is used both for irrigation and filling stock tanks and is therefore in frequent though intermittent use, it is believed to be quite safe to estimate that, allowing for working expenses, interest and depreciation, every cusec—that is, every 375 gallons per minute—does not cost less than £100 per annum. Now the proposed canal will carry 1,300 cusecs; and even if so much as 300 cusecs be allowed for percolation and absorption, the annual value of the net supply reckoned on the basis of the cost of water delivered by pumping is £100,000, or four per cent. on two and a half millions sterling. The significance of this calculation becomes more clear when it is considered that it is very improbable that the whole project will cost one third of this amount. As the supply will be continuous, will involve no capital outlay to the user, and will be delivered in the back country remote from rivers and permanent creeks, it will be of much greater value than a supply on the frontage delivered by pumping, and it will certainly cost much less. The provision of abundant supplies of water to such townships as Urana, Berrigan, Finley, Conargo, and Wangonella, and the utilization of the power which will be made available, important though they are, are merely details in the general project.

Suitable land for irrigation.—The question is sometimes asked whether the great plains in the Central and Western Divisions are suitable for irrigation. In many cases the land-holders have answered the question for themselves, and occasionally the result

is very satisfactory; but sometimes it is not. One case came to the writer's notice, where a landowner erected an expensive pumping plant and proceeded to irrigate land which was little better than a clay pan. The result was that an abundant crop of rushes sprang up, and the owner of that plant came to the sage conclusion that irrigation in Australia is a failure. In regard to this question, instead of advising "to go to the ant and be wise," we might with reason advise an enquirer to "go to the Chinaman and be wise." The Chinaman has never been at a loss to find suitable places for his gardens near towns in the western plains, and whether at Bourke, Brewarrina or Coonamble, at Deniliquin, Hay, or Narandera, he has been able to grow vegetables, and in several cases, fruit with astonishing success. It may with correctness be stated that there are large areas of land in Riverina which are not well suited for irrigation; but in view of the fact that all the water available can irrigate only a small fraction of the area which can be commanded, there is no excuse for including unsuitable areas in this fraction. It should be clearly understood that the main function of irrigation in New South Wales generally and in Riverina in particular, is to provide a certain amount of insurance against the effects of droughts. This it can do on an important scale.

Diversion of river Murray waters below Tocumwal.—While the preliminary surveys and the marking out of a portion of the main canal are the only steps yet taken towards the construction of a canal from the river Murray at Bungowannah, something has actually been done towards increasing the flow in the Edward and Wakool Rivers. A cutting has been made from the river Murray at Tocumwal to the Tuppal Creek, and this carries a supply to the Edward River at a much lower level than formerly. The cutting which has been made from the Edward to the Wakool River is similar in its operation. The effect of these works, and of the cutting which has been made from the Murray River to Eagle Creek, has been to give an increased supply of water in the network of creeks between the Murray and the Edward Rivers. This

increased supply is intended only for stock and domestic purposes, but it may be regarded as a first step towards a larger scheme which will provide water for irrigation also.

Difference between the Murray and other western rivers.—The river Murray, so far as concerns its course in New South Wales differs in one important characteristic from all the other western rivers of this State. Its flow is sufficiently regular and its velocity sufficiently great to keep in check the tendency to silt up, and the consequent tendency to flood increasingly large areas. How far the regime of the river will be affected by the extensive embankments which have been constructed along the Victorian bank remains to be seen; but it is natural to expect that the overflow into New South Wales and the discharge of the Edward River and other northern outflow channels will be increased. It cannot however, be expected that material evidences of the effects of these embankments will appear for a considerable time, as the embankments will not influence the river except in times of flood.

Wentworth irrigation scheme.—It is necessary here to refer to the only irrigation scheme carried out by the Government of this State, which depends on the river Murray for its supply of water. This is the small pumping scheme at Wentworth. The Municipal Council of Wentworth was created an Irrigation Trust by Act of Parliament, and was empowered to pump water from the river Murray for the irrigation of the Temporary Common; but owing to difficulties which the Council experienced, the Government decided to abolish the Trust and carry out a small tentative scheme. This was done, and although, owing to various adverse circumstances, very little land was at first taken up, there now seems every probability that the scheme will ultimately be a success. The total area commanded by the works amounts to only about 1,300 acres.

New South Wales projects as compared with Victorian.—Before leaving the question of the utilisation of a portion of the Murray waters in New South Wales, it may be mentioned that all the

works here referred to or contemplated would have much less effect on the flow of the river than the works which have been constructed or are in progress in Victoria.

First projects for utilising the Murrumbidgee.—The question of utilising the waters of the Murrumbidgee was also taken up by the present writer in 1885. The circumstances connected with the investigation differed from those in the case of the river Murray, as no definite suggestion or proposal had previously been put forward in regard to the latter, while in the case of the Murrumbidgee there was a feeling in favour of utilising Lake Urana for storage purposes and of taking a canal through the Brookong Plain. It was also desirable to find a place at which a weir could be used to divert water on to the north side of the river as well as to the south side. The place which was selected as the best site for a weir to meet the conditions then in view was at Pomingalarna, about six miles downstream from Wagga Wagga. Some years afterwards the surveys were sanctioned, and these showed that a canal could not enter Brookong Plain without passing through a ridge in which the depth of cutting would have reached seventy feet. The result was that the scheme was abandoned on account of the heavy outlay which it would have involved.

The Murrumbidgee northern canal project and Lake Coolacumpama.—The result of the surveys from Pomingalarna on the north side of the Murrumbidgee was also disappointing. The levels showed that a canal could be taken from that place to the great natural reservoir site at Lake Coolacumpama, which is about five miles northward from Narandera, and that this reservoir could be used to store a supply of water in winter which would maintain a large flow in summer, through the great plains extending to Oxley. But the cost of conveying the water to Lake Coolacumpama was so heavy that the scheme could not be recommended under existing circumstances. Before leaving this subject, it may be mentioned that Colonel Home pronounced Lake Coolacumpama to be the finest natural reservoir for irrigation that he had ever seen.

Considering the experience which Colonel Home had whilst his duties as Inspector-General of Irrigation in India made him acquainted with all the important irrigation works throughout that country, this description of Lake Coolacumpama shows that there was abundant reason for testing the practicability of turning it to account.

Practicability of constructing canals below Narandera.—Whilst the surveys showed clearly the impracticability of constructing canals from the Murrumbidjee above Narandera, they showed equally clearly the remarkable facilities which exist for the construction of canals below that place and for the distribution of the water throughout the plains on both sides of the river. A scheme was therefore prepared for a system of canals to distribute water throughout the district between the Murrumbidgee River and the Billabong Creek, involving a main canal following generally the direction of the river and at a distance of fifteen to eighteen miles from it, and branch canals extending south-westerly to the Billabong Creek and north-westerly to the Murrumbidgee. As the levels showed that it was quite practicable to draw off the required supply without incurring the cost of constructing a weir, it was proposed to adopt this course and merely to have regulating sluices at the head of the canal, to control the supply and prevent the ingress of flood water. This was the only part of the scheme with which Colonel Home differed, his reason being that recent practice in India has shown that in the case of a large irrigation canal it is preferable to construct a weir on account of the increased guarantee which it gives of a regular supply. On this account, Colonel Home selected a site for the headworks at one of the few places fairly suitable for the construction of a weir. This affected merely a portion of the main canal, and this portion was altered without delay, and plans of the weir and regulating works for the head of the canal were prepared.

Particulars regarding the proposed Murrumbidgee southern canal —The maximum discharge of the canal as originally proposed was one thousand cusecs, and the rate of fall nine inches per mile, and

these figures were adopted by Colonel Home. Taking the depth of full supply as seven feet and the sides slopes as 1½ to 1, these conditions will require a bed width of about fifty-two feet.

Regularity of outline of the district.—The regularity of the country between the Murrumbidgee River and the Billabong Creek leaves nothing to be desired, the only obstacles of any importance to be found being occasional sand ridges which are easily avoided. At a point about ten miles from the head of the canal, the water can commence to be delivered on the land by gravitation, and thence onward, westerly, south-westerly, and north-westerly, it can be supplied throughout the district. Although the main canal has been marked out only as far as Dry Lake, which is in a south-westerly direction from Hay, it can be taken to the chain of lakes which extend from Yanga to the Edward River. The first place at which the surplus waters of the Murray and Murrumbidgee canals would meet is in the neighbourhood of Jerilderie. From that place the Billabong Creek, and after it the Edward River, will act as an escape channel for all the surplus water of the northern branches of the one canal and of the southern branches of the other.

Storage reservoirs.—A highly important question in connection with canals from the Murrumbidgee and a somewhat less important one in connection with canals from the Murray, is that of storage reservoirs. When the Murrumbidgee southern canal was first proposed, the intention was that the canal should be constructed in the first instance, as it was considered that the abundant supply of water which could be depended on in the spring months, together with the intermittent supplies available in summer, warranted this being done in advance of the provision of a storage reservoir. The result of inquiries which were made in the district supported this conclusion. The intention was to bring the canal into operation, and to deal with the question of a storage reservoir as the demand for the water increased. Colonel Home, however, was in favour of the construction of storage reservoirs at the outset, so that they would come into operation with the canals.

Three excellent sites for storage reservoirs had been surveyed on the upper part of the catchment of the Murrumbidgee, and a preliminary examination was made of two sites on the Murray. The site at Barren Jack Mountain on the Murrumbidgee proved the best in connection with that river, and an estimate of the cost of the Murrumbidgee southern canal scheme, including that of the weir at Barren Jack was prepared. The amount of this estimate, which allowed amply for contingencies, was £650,000, or £650 per cusec, so that reckoning interest at 4 per cent., the interest charge per cusec would be £26 per annum. If the large allowance of two hundred cusecs be made for loss and waste, which is certainly in excess of all the loss to be anticipated, the estimated capital outlay per cusec available for use will be £812 10s., which at 4 per cent. would represent an interest charge of £32 10s. per cusec per annum.

Necessity for storage reservoirs.—With regard to the necessity for supplementing the natural summer supplies in the rivers by means of storage reservoirs, Colonel Home pointed out that for the period of seventeen years, for which records were supplied to him, there were ten years during which the storage on the Murrumbidgee would have been drawn from, and eight years in the case of the Murray.

Murrumbidgee northern canal project.—When it proved that under present conditions of settlement, the project for utilising Lake Coolacumpama could not, on financial grounds be entertained, the general scheme for canals on the north side of the Murrumbidgee was for a time laid aside. The extended survey of the site for a reservoir near Barren Jack Mountain having shown that it was practicable to store an immensely larger body of water than was at first contemplated, it was no longer necessary for the canals north of the Murrumbidgee to depend on Lake Coolacumpama. The levels which had already been taken showed that the facilities for diverting water from the Murrumbidgee on its north side below Narandera, were similar to those on the south side. Examination of the river also showed that near the head of Cudgel Creek,

which flows off on the north side of the river about seven miles below Narandera, there is a fairly good site for a weir. From this place a canal can be taken off and carried through the plains extending to Oxley, with branches extending in a south-westerly direction to the neighbourhood of Carrathool, Hay, and Maude, and north-westerly to near Booligal. These plains are similar in their regularity and general character to those south of the Murrumbidgee, and there is no reason why the water should not be delivered throughout them at an equally low rate of cost.

Rights of the lower landholders.—The question of the construction of large works for water conservation and irrigation on the Murrumbidgee is much more complicated than might at first sight appear. There are extensive properties, chiefly below Hay, which depend very largely on the overflow of the river. This overflow naturally irrigates several hundred thousand acres, besides filling creeks and depressions. A difference of a few inches in the height of the river may mean a difference of many thousand acres in the area flooded. Considering that land which has been flooded will carry from one up to four sheep per acre, while the same land without flooding requires from five to ten acres for every sheep, it is not surprising that those who own such lands view with disfavour any scheme which will interfere with the waters above their properties. Neither is it surprising that they regard with distrust the operation of the two most important outflow channels, namely, Cudgel Creek on the north side of the river, and Yanko Creek on the south side. The objections of the lower holders have not hitherto received the attention they deserve, and while it is intended here to advocate the better utilisation of the Murrumbidgee, and to indicate some ways in which this can be done, it is not intended that this should be done to the detriment of the lower holders, or that their rights should in any degree be overlooked.

Objection to dealing piecemeal with our rivers.—It is unsatisfactory, especially in a country such as this, to deal piecemeal with the waters of any of our western rivers, but it is often

difficult to avoid this course. The requirements of settlement demand attention, and these requirements in times of drought are often of an urgent nature, so that the quickest course of procedure has to be accepted as the best course. It is beyond the province of this paper to discuss the question as to how the difficulties which are liable to arise in this way could be best avoided; but it may be pointed out that much light may be thrown on the subject by examination of the methods which have been adopted elsewhere under similar conditions.

Necessity for storage reservoirs on all western rivers.—While the Murray and the Murrumbidgee require to have their summer discharge supplemented in order to enable them to give regular supplies of water to large irrigation canals, the conditions of all the other western rivers are such as to necessitate storage reservoirs to prevent their flow from stopping altogether, as it occasionally does for considerable periods.

Lachlan, Macquarie, and Gwydir Rivers—drainage project for the Gwydir Marshes.—The Lachlan, the Macquarie, and the Gwydir are in several important respects similar in their conditions. The flow in all of them is very irregular, they all divide into a number of channels from which their waters spread out over large areas of land, and in all three cases no part of their waters reaches the ocean except in high floods. The overflow of the Lachlan and of the Macquarie benefits extensive areas, and converts what would otherwise be a very dry district into valuable pasture land. The Gwydir waters similarly benefit extensive areas, but in a series of wet years the accumulation of water in what is known as "The Watercourse Country" is so great as to make much of the land temporarily useless. Hence in the case of this river there has been a demand for drainage works, and an extensive scheme was prepared on this account some years ago. The area of the land which is liable to be rendered useless for several years together is nearly half a million acres. The estimated cost of the necessary main drainage works was £19,000, and the estimated increase in the capital value of the land to be benefited was £125,000

Drainage not demanded for the Lachlan and Macquarie Marshes. —It would appear that even the highest floods in the Lachlan are regarded as beneficial, as no question of necessity for drainage or of flood prevention has been raised. This may be partly due to the number of lakes and large depressions into which much of the surplus water flows, and which constitute valuable local reservoirs. On the Macquarie there are occasional losses from excessive flooding, but these losses appear to be trifling compared to the benefits arising from ordinary floods, so that here also the question of constructing drainage works has never been seriously raised.

Weirs on the Lachlan and Macquarie.—Weirs have been constructed by the Government on both the Lachlan and the Macquarie for the diversion of water into the back country. The Willandra Weir on the former river was completed in 1890, and was, so far as is known, the first cribwork weir constructed on any river in this State. In the case of both these rivers the channels which are served by the weirs are many hundreds of miles in length. The great benefit conferred on the back country by these works is beyond question; but here as elsewhere in the management of such works the interests of the lower holders have to be kept clearly in view. In the management of rivers and in the distribution of their waters, many difficult and intricate questions as regards water rights have to be dealt with, so that the most vigilant administration has to be maintained in order to hold the scales evenly.

Works for diversion of the Gwydir River.—Works for the diversion of part of the waters of the Gwydir River into the Mornin and Thalaba Creeks were proposed some years ago and have recently been undertaken. In view of the fact that there is an admitted surplus of water on the flats of the lower part of the Gwydir, these works are less likely to give rise to misunderstanding than the corresponding works on the Lachlan and the Macquarie.

The Namoi as compared with other western rivers.—The Namoi occupies an intermediate position between the Murrumbidgee and the last three rivers referred to. Its channel is fairly maintained to

its junction with the Darling, but its flow is liable to complete stoppage. No Government works have been constructed on it, but there are some important private works for utilising part of its waters.

McIntyre River.—A proposal was recommended for investigation some years ago for diverting water from the McIntyre River through Whalan Creek. This is a work of the same class as those in connection with the outflow creeks from the rivers already referred to.

Darling River.—Irrigation works on a large scale are out of the question in connection with any of the rivers north of the Murrumbidgee, and all the more so on account of the extensive areas of land which are naturally irrigated under existing circumstances. The river Darling is included in this category, but it will doubtless eventually have a system of locks and weirs for navigation, and these will greatly improve the facilities for pumping water for irrigation. While it is improbable that any great area will be irrigated at any one place in this way, the aggregate area, owing to the great length of the river is certain to be considerable.

Next to really suitable conditions for the settlement and tenure of the land, the most important question in connection with the western part of the State is the conservation and utilisation of the available supplies of water. While the progress made in this direction is much less than might reasonably have been hoped for, it must be borne in mind that until the Water Rights Act of 1896 came into operation, the construction of dams and other works for conserving and utilising the waters of creeks and rivers was entirely unauthorised, and such works when constructed were allowed to exist and be used on sufferance only. In view of this state of affairs, it is in reality surprising that so much was done by the landholders, especially when it is considered that besides having no security for their water supply, the terms of the tenure of their land were in many cases far from being so liberal as the conditions of climate required.

As regards the small amount of progress towards the carrying out of large works and of extensive systems for water conservation and supply, the delay will not be without its benefits if the experience gained elsewhere, both as to what should be done and to what should be avoided, is properly acted on, not only in the design and construction of works, but also in their management.

On the principle of CONTINUITY in the GENERATION of GEOMETRICAL FIGURES in PURE and PSEUDO-HOMALOIDAL SPACE of n-DIMENSIONS.[1]

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[*Read before the Royal Society of N. S. Wales, December 4, 1901.*]

[1] The term dimension is used in the sense that a line is essentially of unit dimension, a surface 2-dimensional, a volume 3-dimensional, and so on. The space of points and planes, is sometimes said to be of three dimensions; but of lines, of four dimensions, *e.g.*, as by Henrici.

24. Is elliptic and hyperbolic space of n-dimensions representable in space of $(n+1)$ dimensions?
25. Elliptic and hyperbolic space merely a specialised region in a homaloid.
26. Space of n-dimensions as the boundary of $(n+1)$ dimensional space.
27. Relativity of geometrical forms and figures.
28. Complex generation of geometrical figures of uniform intensity.
29. Involutional, evolutional, pedal, modular and umbilical generation.
30. Generation of figures of non-uniform intensity.
31. The total intensity-volume of æolotropic space.
32. Conversion of æolotropic into isotropic space.
33. Conformal representation of functional dependence.
34. Riemann surfaces.
35. Connectivity of space.
36. Conception of n-ply extended magnitudes.
37. Illimitability of operative schemes for generation of geometrical figures.
38. Pangeometry.

0. *Introductory.*—The discussion of the elementary principles of geometry, has of late years received so much attention, in connection with what has been called non-euclidean geometry, and with the theory of space generally,[1] that further contribution thereto might be thought supererogatory. It has been imagined that the spatial interpretation of the "purely abstract methods of analytical geometry"[2] require a more generalised theory of space than that which is implicitly contained in euclidean geometry, and in this more generalised theory, space is not only to be con-

[1] The following are some of the leading contributors to non-euclidean geometry:—Lambert 1786; Lobatchewsky 1826; Gauss '28; J. Bolyai '32; Perronet Thompson '33; Jacobi '34; Sohncke '37; Grassmann '44; Cayley '45; Grassmann '47; Riemann '54; Cayley, Hoffmann '59; Delboeuf, Young '60; Hoüel, Beltrami, Helmholtz '66; Witte '67; Plücker, Baltzer, Battaglini, Helmholtz, Geiser '68; Kronecker, Christoffel, Clifford, Lipschitz '69; Schlaefli, Flye '70; Beez, Rosares, Lie, Klein '71; Saleta, König, Jordan, Frischauf, Kober '72; Hoffmann, Freye, Cassani, Frahm '73; Grassman '74; Halphen, Erschenck, Spottiswoode, Lewes, Hoüel, Funcke '76; Zöllner, Frank, Engel, Liebmann, Lüroth, Günther '76; Réthy, Frankland, Erdmann, Mehler, Cantor, Newcomb, Tannery '77; Weisserborn, Land, Krause, Land '78; Schlegel '79; Smith, Ball, Chrystal '80; Veronese, Story '82; Killing '85; Dixson '88; Segre '90?; Gerard '93; Mansion, Schubert, Halstead '94; Stäckel, Veronese '95; Russell '97; Poincaré, Ball '98; Stringham '99.

[2] On the origin and significance of geometrical axioms. v. Helmholtz, 1870.

ceived as having an indefinite number of dimensions, but also as possessing positive or zero curvature.[1] It is easy to see that the introduction of such ideas into the theory of space, in no way exhausts its possible complexity. Thus conceptually, there may be *tridimensional tortuous space*, and even n-dimensional space of manifold tortuosity, in exactly the same sense as there may be "*curved space*," though the development of the geometries of these has not so far been attempted. There is in fact *no limit* to the complexity of conceptual space. To anyone, however, who is sufficiently a Kantian[2] to still believe that the limitless infinity of tridimensional homaloidal space[3] is the form in which the intellect, by its original constitution, is forced to interpret all natural phænomena, the interpretative argument of the non-euclidean geometers appears to be wrongly founded. This is assuredly so if the ordinary conception, at least when clearly realised through attention to the matter, is not only the most comprehensive, but is also the background against which as it were, the lineaments of other geometries[4] are revealed, and without which they would remain unintelligible. No argument can logically be founded on analytic, *i.e.*, algebraic geometry, taken by itself, for it is evident that the quantitative expressions both in arithmetic and algebra, are not in themselves a geometry, though within certain limits, and subject to certain restrictions they are *susceptible of a geometrical interpretation*. At best they cannot

[1] 'Space of positive curvature' or 'synclastic space' is now generally known as 'elliptic space.' In the geometries of such space, Klein distinguishes between the 'polar' and 'antipodal' forms, calling the former 'elliptic,' and the latter 'spherical geometry.' 'Space of negative curvature,' or 'anticlastic space' is similarly called 'hyperbolic space,' and its geometry known as 'hyperbolic geometry,' or 'pseudospherical geometry.' The limiting form between the two is 'parabolic space' or 'homaloidal space.' Whitehead, however, evidently regards this last as an unsound definition, see his Universal Algebra, Vol. I., p. 451 (footnote) 1898.

[2] Helmholtz imagined that Kant fell into error in the matter of the 'axioms of intuition.'

[3] Space in which if two points be taken, one, and only one straight line can be drawn; or if three points be taken, one and only one plane can be drawn.

[4] Such as those of curved space, or those of space of manifold tortuosity.

be more than symbolic results,[1] formally deduced, and their *translation* into geometry cannot transcend the conceptions of geometry itself.[2] Therefore notwithstanding the advantages of the application of algebra to geometry—*i.e.*, the construction of an "analytic geometry," algebraic in form—no fundamentally new conception, not already implicitly contained in the original assignment of meaning to the symbols, can really arise, inattention to which matter may lead, and actually has led, to erroneous conclusions.[3] We may say broadly, therefore, that geometrical conceptions are essentially independent of all schemes of formulating them symbolically, or translating them from symbols.[4] It is of course

[1] It is often forgotten that the significance of the algebraic expression is *not* inherent, but is determined by pure convention. The reader unfamiliar with the algebra of symbolic logic will realise the truth of this from such expressions as $a+a=a$; $a+0=a$; $aa=a$; $a+ab=a$; $ai=a$; $x+\bar{x}=i$; $x+i=i$; $x\times\bar{x}=0$, which are some of the general formulæ of that algebra. See Universal Algebra—Whitehead, Bk. II., Cap. I., pp. 35-39, 1898.

[2] For example, the algebraic expression $y^2=ax$ has *per se* no geometrical meaning, but if y be intended to represent a line on a surface, parallel to a y-axis thereon, and x a length on the x-axis, the *relation* between the two being expressed through the equation, then the expression represents for plus values of x, a parabolic curve. But retaining the ordinary conventions of abstract arithmetic, there is a difficulty as to whether the expression has *any* meaning for minus values of x. The determination that i or $\sqrt{-1}$ shall be taken to represent a quantity perpendicular to the surface is a purely arbitrary *convention*, or scheme, which will admit of more or less consistent interpretations, and the algebra does not *prove* that the imaginary parabola for minus values of x has its plane perpendicular to the xy surface. Strictly the equation implies the existence only of surface, viz. that in which x and y lines exist, and an zx surface has no implied existence, and therefore there is no *intelligible* interpretation when x is negative. See § 33 hereinafter.

[3] Chrystal remarks:—"It seems to be forgotten by some writers that the e in $e^{i\theta}$ is a mere *nominis umbra*—a contraction for the name of a function, and not 2·71828. . . Oblivion of this fact has led to some strange pieces of mathematical logic." Text Book of Algebra, Vol. II., p. 264.

[4] Tait says, "it was reserved for Hamilton to discover the use of $\sqrt{-1}$ as a *geometric reality*"—the italics are his; see Quaternions, chap. I., sec. 18—"tied down to no particular direction of space." Is not the essence of the matter more perfectly stated by Argand's title:—"Essai sur *une* manière de représenter les quantités imaginaires dans les constructions géométriques"? (1806). Wallis [1616-1703] proposed to construct imaginary roots by going out of the line on which if the roots were real they would be constructed, see his Algebra 1685. H. Kühn of Danzig in 1750-1 represented $a\sqrt{-1}$ as a line of the length a perpendicular to the line a. Reference is made to this particular symbol because of the signal part it has played, through the work of Gauss, Cauchy, Riemann and others, in the modern theory of functions. See § 33 hereinafter.

true that there is a remarkable (but not complete) parallelism between purely numerical and ordinary algebraic operations and their geometrical interpretation; that the limits to the parallelism have to be determined independently of the arithmetic or algebra, is evidence of their real or essential independence.[1]

In algebra we have a conceptually loose method of treating infinitesimals as zeros,[2] because as a rule, that procedure does not lead to practical error; but there is a real difference between an infinitesimal and an absolute zero which ought not to be disregarded when we are dealing with the fundamental conceptions of algebra or of 'analytical,' *i.e.* algebraic, geometry. If *a* and *b* are the terminals of a straight line, we may say that from any point *c* *not* in the line, but opposite say its centre, that the lines *ca* and *cb* approach more and more closely to the one straight line as *ab* is increased in length; but it surely is not correct to say that when *a* and *b* are each infinitely distant, *ac*, *cb* are one and the same straight line: they differ by a small but real angle; that is to say the angle *bac* is infinitesimal, but the angle *bab* is nought.

Our knowledge that two straight lines can intersect but once,[3] does not depend upon spatial or physical experiment; and the fact

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[1] This may be simply illustrated as follows:—If a, b, and c are ordinary numbers, and algebraically $ab = c$, we can find a number d, such that $d = \surd c$, if c be positive. If a alone be an abstract number, b_x the number of units on a line x, then $ab_x = c_x$, and $dd_x = c_x$, nevertheless there is no such thing as the square root of a line: therefore the operation $\surd c_x$ is really impossible. The result that the unit d_x repeated d times is equal to c_x, is an *interpretation* through which an essentially impossible operation may nevertheless be assigned an arbitrary and yet consistent meaning. The symbols $a_x b_y = d_x d_y = c_{xy}$ may be thought to be unambiguous, but it may easily be verified that in geometry $(-a_x)\ (-b_y)$ is *not* the same surface as $(+a_x)\ (+b_y)$, therefore the product of two negatives, is not always the same as that of two positive numbers.

[2] The zero in $+a - a = 0$, may be called an *absolute* zero or nought: the plus sign signifies the positing of the quantity a, the minus its removal again, hence *nothing* is left. Infinity multiplied by this nought or zero yields nothing, *i.e.* $\infty \times 0 = 0$. We call also $a \div \infty$, zero, this is really an infinitesimal and *not* nought; *i.e.* if a is an angle, line, or space, it is an infinitesmal angle, line, or space. In this case we have $\infty \times 0 = a$ instead of 0. It is because zeros do not always mean the same thing that $0/0$ and $\infty\, 0$ etc. are indeterminate.

[3] Chrystal states that '*Experience* does not settle the question.' Proc. Roy. Soc., Edin. x., p. 641. For reasons which are later given it may also be said that it would be idle to attempt to settle it by *experiment*.

that their *analogues*[1] on surfaces, that to us may be physically undistinguishable from planes,[2] may do so, does not in any way qualify our assurance. Poincaré goes to the root of the matter when he says that "*geometry is not an experimental science.*"[3] All ratiocination concerning spatial conceptions would assuredly be futile unless the straight lines of homaloidal space were the conceptual background for comparison with other geometrical forms or figures. The straight line of geometry is in fact *not* a physical entity to be examined, tested, and experimented upon in order that its properties may be disclosed. To attempt to physically delineate a straight line, as by optical methods[4] would, apart from the consequences of the exceedingly complex nature of the earth's motion in space,[5] be involved in difficulty and uncertainty owing to our ignorance of the physical (?) substances distributed therein, and their effect on the delineation, and would require an antecedent knowledge of what was meant by such a line. In drawing a representation of any conception, our ratiocination is always guarded against both error of drawing and the limitations of drawing itself.

Nor is the straight line a thing to which position in the external world has to be assigned in order to discover whether in particular directions it may change its properties. It and the other elements of space, *i.e.* surface, volume, etc., viz. the entities with which geometry operates, are conceptual, so that geometrical ratiocination depends, not upon the physical constitution of the universe, nor on the contents and properties of stellar space, but rather upon our mental constitution, and the terms in which we are compelled by that constitution to translate experience. Hence its relation to the physical world is indirect. It is only when we

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[1] Geodesics. [2] That is homaloidal plane-surfaces.

[3] The Monist, Vol. IX., p. 41, 1898.

[4] An idea which has presented itself to Lobatchewsky, Hoüel, Chrystal and others.

[5] Though to the beholder the path of a moving point may be *straight*, the actual motion is, even so far as we know complex almost beyond description.

represent elements of that world in geometrical form, that geometry becomes applicable, and even then not to the thing, but merely to its representation.[1] The notion that had we a larger opportunity of experiment, the question as to the nature of space itself, might (supposititiously) be determined, fails to recognise that *unoccupied space* must[2] physically be regarded as perfectly homaloidal and homogeneous, and that observed physical facts must necessarily be interpreted ultimately on that basis, as being essentially the most simple; for an explanation which assumed changes in the curvature and intensity of space would be *essentially*, though not *formally*, identical with one that assumed these to be due to variations in the æther in space. Negative parallax for distant stars would involve a modification of our conception of the content of stellar space; *i.e.* it would involve a physical and not a geometrical explanation,[3] although an analytical geometry might be developed which could formally represent the essential features of the æthereal modifications.

Among conceptions that have been regarded as throwing new light on the theory of space Riemann's notion of an n-ply extended magnitude[4] has been assigned a prominent place.[5] But Riemann

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[1] Hence essentially, geometry is independent of the physical point of view, and of physical interpretations, though of course both the original representation and final interpretation may be false. For example, we may elect to regard the sun as a fixed point, and a comet as a point moving in say a parabolic path about the sun as focus. With the very same system of celestial coordinates, the sun would appear to the comet (the latter being regarded as the fixed point) to move about it in the same curve and in the same direction, the coordinates however differing 180°. Hence the curve is parabolic in either sense, but may, in reference to some other fixed point, be quite different.

[2] For to suppose otherwise would require the support of some considerations, justifying the substitution of the complex for the simple idea.

[3] Lobatchewsky's deduction that the negative parallax of some stars could possibly throw light on the nature of abstract space is therefore, I think wrongly founded.

[4] [1826 - 1866]. Ueber die Hypothesen welche der Geometrie zu Grunde legen. Abh. d. k. Ges. a. Wiss. Göttingen, Bd. XIII., 1868. Annali di Math. III., pp. 309, 326, 1869-70. Nature, VIII., pp. 14-17, 36-37, 1873.

[5] By Helmholtz, Clifford, Chrystal, and others. I need hardly say that anyone who takes the trouble to acquaint himself with the part played by the Riemann's surfaces, as developed for example in the very fine treatises of Whitehead, Forsyth, and Harkness and Morley (Universal Algebra, and Theory of Functions and Analytic Functions) is not likely to lightly esteem the significance of Riemann's work.

surfaces are spatial in the ordinary sense, and their geometries may, like the geometries of regular surfaces of various kinds, be regarded as systems of theorems and problems, restricted to the several surfaces: and generally it may be said that the non-euclidean geometries are really geometries of surfaces, or of specially constituted regions of space, rather than geometries which have some peculiar applicability to a supposed actual (?) space itself.

A region of absolutely homogeneous homaloidal space of three dimensions, may be supposed to contain some physical entity subject to a definite variation dependent upon its position therein: the physical element after it has been mathematically specified may be disregarded, and the region treated as a specially constituted region of space, for which a special geometry may be created: such a geometry might be of the same number of dimensions but would have special features. And further, a region of space may involve the idea of such special constitution as has been indicated, and be moreover affected in some other way, also susceptible of mathematical specification. In such a case the specialised geometry would need a further dimension: that is to say it would be four-dimensional as well as special in its other features. There is no limit to the development of dimensions, or the intricacy of a conceptual constitution of space, and the analogies derived through surfaces of positive and negative curvature, and from variations of linear intensity in projections, are from this point of view easily seen to be after all only the *simplest* developments of pangeometry, the possibilities of which are doubtless absolutely inexhaustible.

It is proposed in the following paper to discuss the generation of geometrical figures in homaloidal space of n-dimensions, with a view to elucidating what is involved in the conception of absolute continuity, and of shewing that there need be no confusion in respect of the infinitesimal, 0^n say, and the absolute zero, *nought*. In doing this, the purview will be extended to the regions of non-euclidean geometry with a view of shewing that after all it may

be regarded and understood as really a form, or rather a development, of euclidean and projective geometry.

As the subject is of interest to thinkers generally, the introduction of the more specialised forms of mathematical expression and symbol, have been studiously avoided. For the same reason the conceptions have been set forth with more fulness than would be deemed necessary by the professional mathematician, to whom therefore apology is not required.

1. *The dimensionless point as generatrix.*—The ultimate *element* from which all geometrical figures may be generated is the *dimensionless point.* Since conceptually this is without magnitude[1] and may be said to be sensibly non-existent, its spatial *dimension* is appropriately represented by that symbol which in number implies negation, *i.e.* 0. Consequently a point, *per se*, may be defined as an entity of zero-dimension.[2] Having no spatial dimensions, even as we shall see, of zero-order, it nevertheless may serve to conceptually define position. This type of point we may call the *pure* or dimensionless point, to distinguish it from a zero or infinitesimal quantity, possessing dimensional properties, which also is often loosely called a point; and is really the *monad* of geometrical figures. The use of abstract numbers, including 0, to define the dimensions of space, can lead to no ambiguity, so long as the sense in which they are employed is not permitted to vary. The parallelism of dimensional significance in different conceptions of space and spatial quantities, is an independent question. Whereever parallelism really exists, it may, in practical applications, occasionally relieve to some extent the necessity for rigour of thought; but in theoretical considerations such relief can not be permitted.

2. *Summational generation impossible with dimensionless point.* —In considering the point as the generatrix of all geometrical

[1] Euclid's definition really exhausts the conception. The point has locus, but *no* magnitude, not infinitesimal magnitude.

[2] An entity of zero-dimension is not to be confounded with a zero quantity generally, nor is it to be assumed, even in abstract numbers, that zeros are necessarily identical.

figures, two fundamental ideas of generation are naturally suggested; (*a*) the idea of summation or addition; (*b*) the idea of fluxion or motion. The former idea was Cavalieri's,[1] the latter Robervals'[2] and Newton's.[3] Since as defined, the point is of zero-dimension, the continuous[4] generation of a finite quantity by a finite number of *additions*, is clearly not a conceptual possibility. It is however by no means *obviously* inconceivable that such a quantity can be continuously generated by an *infinite* number of point-additions, since this was the essential feature of the Cavalieri-Guldinus-[5] and Pascal-[6] controversy, which embraced also the same question in respect to the possibility of lines and surfaces building up respectively surfaces and solids.[7]

So long as points and infinitesimal lines are recognised as different in *kind*, there can be no suggestion that any number, finite or infinite, of points, point-elements, or groups, can constitute a line or line element:[8] that is to say, there must be a *generic identity* between the constitutive points and the line constituted.

In considering the generation of geometrical figures as space, whether by summational, fluxional, or other operations, it is to be observed that the *space itself is not the subject of generation.* Whatever its dimension, *its existence is merely postulated* as conceivable,[9] and it is the *geometrical figure* therein that *is alone the*

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[1] [1598 - 1647] Professor of geometry at Bologna. See his Geometria indivisibilibus continuorum nova quadam ratione promota. 1635. Also, Exercitationes geometricae sex. 1647.

[2] [1602 - 1675] Mém. de l'Acad. roy. des Sciences, t. VI.

[3] [1642 - 1727] Philosophiae Naturalis Principia Mathematica, 1687.

[4] See Aristotle's Category No. 6 and Boscovich, [1711 - 1787] De continuitatis lege.

[5] [1577 - 1643] Author of 'Centrobaryca.' [6] [1623 - 1662] About 1658.

[7] Sensibly of course even a *finite* number of visible or sensuously perceived points may appear to constitute a finite *visible* line: conceptually the scale of separation is of no moment *even though infinitesimal.*

[8] The essence of the Guldinus' reply to Cavalieri, and to which the rejoinder of Pascal is directed in his letter to de Carcavi, 1658.

[9] This may be put even more strongly. Thus Kant "Der Raum ist kein empirischer Begriff, der von äusseren Erfahrungen abgezogen worden." Der transscendentalen Aesthetik. Absch. 1 § 2 (1). "Der Raum ist eine notwendige Vorstellung, *a priori.*" ibid. (2). Quite recently Poincaré writes, "Geometry is not an experimental science. . . . . the geometrical ideas . . . preëxist in us." Monist, Vol. IX., Oct. 1898 p. 41. The matter has been fully discussed by Lotze. Metaphysik II., 1 and 2, § 99 - 137.

subject of generation. Consequently, the dimensions of geometrical figures are limited to the conceivable dimensions of the space in which they may be supposed to exist, but can never transcend it.[1]

The rigorous conception of the *pure* or dimensionless point is that it can exist in space, can define position, but is itself *absolutely* without spatial magnitude.[2]

This is brought into conceptual relief by considering that the interpolation of any number of points, represented by the symbol ∞, between two terminals, separated, let us suppose, by a unit distance in linear or 1-dimensional space, leaves $\infty + 1$ linear elements or parts of the unit, each susceptible, conceptually, of similar subdivision, no matter how great the number may be. If we suppose ∞ to denote an infinite number[3] the concept remains unchanged, for there is nothing whatever to suggest that as the number increases there is any tendency to *generic* change. Thus we may say there are $\infty + 1$ infinitesimal linear-elements divided by ∞ dimensionless points. It is not the summation of the infinite series of points[4] which constitutes the unit-line, but the summation of the infinite number of infinitesimal lines;[5] which those points conceptually separate; the essential difference between these two ideas being that in the one case there is a discrete series or *assemblage* of dimensionless points, infinitesimally approximating to continuity, *i.e.* conceptually discontinuous, in the other there is a series of infinitesimal but *not* dimensionless lines, schematically

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[1] See Hermann Schubert—The fourth dimension. Monist, Vol. III., pp. 402–449, April 1893. Also, On the nature of mathematical knowledge. Monist, Vol. VI., pp. 294–305, 1895-6.

[2] Point-contact, is therefore coincidence, if the points be dimensionless. Kant, 'Raum und Zeit sind *quanta continua*. . . . Der Raum besteht also nur aus Räumen. . . . Punkte sind . . . nur Grenzen, d. i. blosse stellen ihrer Einschränkung; stellen aber setzen jederzeit jene Anschauungen, die sich beschränken oder bestimmen sollen, voraus, und aus blossen stellen, als aus Bestandteilen, die noch vor dem Raume oder der Zeit gegeben werden könnten, kann weder Raum noch Zeit zusammengesetzt werden.' Kritik d. rein. Vernunft. Elementarlehre, Buch II., 2, 3, § 2.

[3] Greater than any assignable or finite number.

[4] See Kant, preceding footnote.

[5] Cavalieri's indivisibles, must be conceived as schematically indivisible, rather than as conceptually indivisible.

separated by dimensionless points, *i.e.* not really separated at all.[1] Algebraically we may say that if m and n denote abstract numbers, and p and q characteristic suffixes defining the kind of units to which they are appended, no relation can exist between[2]

$$m \times 1_p \text{ and } n \times 1_q$$

unless it can be established between 1_p and 1_q. It matters not what magnitude m and n have, if 1_p denotes a point, and 1_q a line, no direct relation can exist between m_p and n_q even if m be an infinity, or an infinity of infinities.

Hence no number of pure points can constitute a line, and similarly since a line is without breadth, no number of lines can constitute a surface, and for the same reason no number of surfaces a solid.

3. *The straight line.*—Before considering other modes of generating geometrical figures, the nature of the second important conception of geometry, viz. the *straight line*, may be examined. The definition that this is *the shortest distance between two points*[3] is unsatisfactory, inasmuch as that property is deducible rather than immediately evident; and furthermore when restricted to a surface, the geodesic also answers to the definition. There is still another objection, the most cogent of all, viz. that the definition

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[1] Clifford, [1845 - 1879] referring to Plücker's mode of generating curves says:—'now a point is absolutely *no* line, as a line is *no* surface and a surface *no* space.'—Math. Papers, p. 40. Thus Kant: 'Raum ist ein solches Ganze, dessen Teile bei aller Dekomposition immer wiederum Räume sind, und ist daher ins Unendliche teilbar.' . . . 'Die unendliche Teilung bezeichnet nur die Erscheinung als *quantum continuum* und ist von der Erfüllung der Raumes unzertrennlich; weil eben in derselben der Grund der unendlichen Teilbarkeit liegt. Sobald aber etwas als *punctum discretum* angenommen wird: so its die Menge der Einheiten darin bestimmt.'—*Op. cit.*, Elementarlehre, Buch II., 2, 9, i.

[2] In the language of vector algebra and quaternions m and n are scalars, 1_p and 1_q unit vectors of different kinds.

[3] This quantitative definition has been strongly approved. A. M. Legendre, Eléments de Géométrie. B. Pierce, An elementary treatise on plane and solid Geometry: Helmholtz, Henrici, and many others. Wilson (Elementary Geometry) defines a straight line as "that which has the same direction at all parts of its length." The Assoc. Impt. Geom. Teaching (1878) "A straight line is such that any part will, however placed, lie wholly in any other part, if its extremities are made to fall on that other part." Chrystal, Proc. Roy. Soc., Edin. x., 642, says "Two points *in general* determine a straight line."

does not reveal the *essence* of the matter: *this criterion* or test, viz. shortness, *is not that which affords either the best evidence or the fundamental idea of the property defined.* Consider for instance any arc ACB of a circle, C being the middle point, and M the middle of the chord. When the distance between M and C is small, the difference in the *shortness* between ACB and AMB is very much smaller.[1] Suppose that e were the smallest perceptible difference in length, then the departure from straightness would be no less than the relatively enormous quantity

$$h = \sqrt{(\tfrac{3}{8} Se)} \ldots\ldots\ldots\ldots\ldots (0)$$

in which h denotes the distance MC, and S the length of the arc. Or to state this conversely, if h be the limit of perceptible quantity, the difference of length

$$e = \frac{8h^2}{3S} \ldots\ \ldots\ldots\ldots\ldots (0a)$$

is quite beneath the limits of perception. This may be still more strongly stated: if h be an *infinitesimal quantity*, then e is *infinitely smaller*,[2] and therefore *at the limit, the criterion utterly fails*: that is to say, it is *not* a criterion for the determination of extremely small curvature.

It is evident therefore, that MC or h affords a better—and in the limit an infinitely better—measure of straightness than the difference of the arc and line, *i.e.* than *shortness*, a result confirmed alike by common sense, by the ordinary methods of testing straightness, and by analytical theory.

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[1] The versed sine (*i.e.* the distance from chord to curve, MC $= h$) divided by the difference between the arc (ACB $= S$) and the chord (AMB $= s$) is:—

$$\frac{h}{S - s} = \frac{1 - \cos \frac{1}{2}\theta}{\theta - 2 \sin \frac{1}{2}\theta} = \frac{3}{\theta} \left(1 - \tfrac{1}{120}\theta^2 - \tfrac{1}{201600}\theta^4 - \text{etc.}\right)$$

θ being the angle subtended by the arc ACB. As the arc approaches straightness *i.e.* as θ approaches zero, h becomes vastly better than $S - s$ as a *measure of straightness* and at the limit is *infinitely* better. The above expression may be put in the form

$$\frac{h}{S - s} = \frac{3s}{8h} \left(1 + \frac{4h^2}{5s^2} \text{etc.}\right) = \frac{3S}{8h} \left(1 - \frac{28}{15} \frac{h^2}{S^2} \text{etc.}\right)$$

which confirms the preceding statement, for as h becomes very small, the ratio becomes very great, and when h is an infinitesimal, the ratio is infinite.

[2] The non-mathematical reader will see later some remarks concerning the meaning of these expressions.

It has been seriously proposed by some mathematicians that the *nature of space itself*,[1] should be ascertained by experiment.[2] Any essay of that character would necessarily have to rely upon a better definition than that a straight line is the shortest distance between two points. Euclid's definition, although perhaps not sufficiently explicit, goes to the heart of the matter, viz. "a straight line is that which *lies evenly* between its extreme points,"[3] a definition which Henrici states "must be meaningless to anyone who has not the notion of straightness in his mind."[4] Probably no one who ever had any capacity for geometrical thinking ever failed instantly to grasp what was intended by Euclid's definition, whereas the quantitative definition which relies upon shortness is not only *not* obvious, but is meaningless *unless the idea of straightness is already in the mind.* The apodictic certainty with which straightness is conceptually distinguished from even infinitesimal curvature, confirms the opinion that it is intuitive.[5] As an elementary definition is Euclid's susceptible of improvement?

The test of straightness indicated in Euclid's definition, despatches at once the doubts raised in the non-euclidean geometry, even to beings limited to perception in two-dimensional space.[6] If it be possible to rotate a line round itself as axis, either one point

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[1] Not of space filled with some medium whose physical properties may properly form the subject of inquiry, but space *per se*.

[2] Euclid and some other geometers have been supposed guilty of the philosophical immorality of making assumptions which 'Experience' might shew to be invalid. It is not clear upon what ratiocinative basis the objectors propose to *interpret* 'Experience.'

[3] Euclid's definition is:—"Εὐθεῖα γραμμή ἐστιν, ἥτις ἐξ ἴσου τοῖς ἐφ' ἑαυτῆς σημείοις κεῖται," which is translated by Simson, "Recta linea est, quæ ex aequo suis interjicitur punctis." Proclus explains ἐξ ἴσου as being stretched between its extremities, ἡ ἐπ' ἄκρων τεταμένη. The reader interested in discussion on modern proposals to supersede Euclid's definition, will find "Euclid and his modern rivals"—by C. L. Dodgson. Macmillan, 1879—well worth reading.

[4] Encyc. Brit. x., 376.

[5] Chrystal states, *loc. cit.*, p. 641. "We have by generalisation from experience (!) ideas more or less refined . . . . of a geometrical straight line, etc." See previous footnote 3, p. 247.

[6] Say the sphere or pseudo-sphere dwellers of Helmholtz, *vide* On the origin and significance of geometrical axioms. Trans. Atkinson, pp. 34 – 44, 60 – 68.

only of two points, being fixed, in such a way that there will be no spatial displacement of any part of it, the line "lies evenly between its extreme points," *i.e.* it is uniquely straight. The complete test of straightness requires that the line be free to rotate about the line joining its terminals, the last being fixed: then whatever its shape the mean position is a uniquely straight line.[1]

The normal geometry of any number of dimensions presupposes straight axes in the euclidean sense, *i.e.* that the space is homaloidal in every direction. When other suppositions are made the geometry is merely specialised.

4. *Fluxional generation by means of dimensionless point.*—The generation of an n-dimensional geometrical figure, in conceptual space of the same number of dimensions, by continuous motion[2] or displacement therein, of an $(n-1)$ dimensional generatrix, presents no conceptual difficulty.[3] We may say that, *in general*, motion of

[1] In a two-dimensional space the line cannot remain thereon if it be not plane: and if the line be not straight. Consider the rotation of a segment of a small circle on a spherical surface; rotation about its terminals would give two positions on the surface the mean of which would be a great circle thereon. The lengths of several segments, of different radii, the radii of the circles of which they formed part, and the distances between the opposite positions, would enable Helmholtz's intelligent sphere-dwellers to ascertain the dimensions and form of their world, and they could arrive at the theory of the unique straight line, of a homaloid of two dimensions, and would know the phænomena involved the supposition of a curvature, the radius of which was (to them) "imaginary."

[2] According to Henrici it appears impossible to avoid the introduction of the idea of motion in geometry. Would it not be more rigorous to qualify this by adding "if it is to explain the development of geometrical figures, consistently with the principle of continuity, with the dimensionless point as generatrix." See Encyc. Brit. 9° Edit. x., 376.

[3] It may, however, be thought by some open to doubt whether *psychologically* we are able to distinguish between successive apparitions at dimensionless points infinitesimally separated, and continuous motion along the range or path in which the points lie. It might be urged that in representing the path of a continuously moving generatrix, a point say, we leave as it were in imagination a trail of points in order to fix our ideas, and that this exhausts the motion of a path, provided the points are conceived to be separated by infinitesimal distances; for—it may be alleged—the infinitesimal marks the limit beyond which mental representation fails, or we may conceive of continuity as apparent, as in the kinetoscope. The fact that we can conceptually distinguish between, as well as symbolically represent and operate upon, different classes of zeros,

a point generates a line,[1] of a line a surface, of a surface a volume, etc.; or adopting Henrici's definitions the *path* of a point is a line, of a line a surface, and of a surface a volume. The qualification 'in general,' logically fatal to a definition, is avoided by properly characterising the essential nature of the generative motion, viz. that it shall be into a new spatial dimension. A point moving in its 0-dimensional space does not generate a line or 1-dimensional geometrical figure, similarly a line moving in its own path or the continuation of its path, *i.e.*, in its own 1-dimensional space, generates only a 1-dimensional figure, viz. a line and not a surface, and, identically an $(n-1)$-dimensional geometrical figure will generate a figure of only the same dimension unless its motion take place into the nth dimension itself, when it will generate an n-dimensional figure.

Whether finite, infinite or infinitesimal, the scheme of generation is completely defined by the following system, in which the symbol $\longrightarrow$ denotes an operator, translating the quantity on its left, the amount and direction specified by the quantity on its right, the axes, to which the motions are to be parallel, being x, y, z, w, etc.

$$\begin{array}{llllll}
1_0 \longrightarrow 0^1_x \equiv 0^1_x & ;\ 1_0 \longrightarrow 0^1_y \equiv 0^1_y & ;\ 1_0 \longrightarrow 0^1_z \equiv 0^1_z & & & ;\ \text{etc.} \\
0^1_x \longrightarrow 0^1_y \equiv 0^2_{xy} & \equiv 0^1_y \longrightarrow 0^1_x \equiv 0^2_{yx} & ;\ 0^1_y \longrightarrow 0^1_z \equiv 0^2_{yz} & & & ;\ \text{etc.} \\
0^2_{xy} \longrightarrow 0^1_z \equiv 0^3_{xyz} & \equiv 0^2_{xz} \longrightarrow 0^1_y \equiv 0^3_{xzy} & \equiv 0^2_{yz} \longrightarrow 0_x \equiv 0^3_{xyz} & & & ;\ \text{etc.} \\
0^3_{xyz} \longrightarrow 0^1_w \equiv 0^4_{xyzw} & \equiv 0^3_{xyw} \longrightarrow 0^1_z \equiv 0^3_{yzw} \longrightarrow 0^1_x & \equiv & & 0^4_{xyzw} & ;\ \text{etc.} \\
\text{etc.} \qquad\qquad \text{etc.} & \text{etc.} \qquad\qquad \text{etc.} & & & \text{etc.} & \text{etc.}^2
\end{array}$$

proves that the ratio or relation of quantities may be conceptually retained up to point of their evanishing, that is to say, their zeros have definite relations, if the law of relation is susceptible of being continuously expressed. It is only when the facts are represented as being sensuously perceptible that each point is surrounded by a "circle of confusion," through which it fuses with its neighbours.

[1] In Henrici's definitions the qualification 'in general' is not applied to the motion of a point. The conception of motion into a new spatial dimension, hereinafter mentioned, shews that logically this case should not be excepted.

[2] The idea of successive infinitesimal motions, and infinitesimal *paths* produced thereby, may be clearly apprehended by conceiving it as the actual path of the generatrix during the time, $1/\infty$ multiplied into the unit of time, the last being understood as the interval of time necessary for the generatrix to move over a unit in any particular axial direction. Let 1_t denote such a time unit, then $1/\infty \times 1_t = 0_t$, a zero of duration, but

And instead of 0 we may substitute 1 throughout for units of successive dimensions, and ∞ for infinities of the successive dimensions.

Similarly if we start with the line px, move it qy, then move the generated surface rz, etc., we obtain

$$\{[(p_x \longrightarrow q_y) \longrightarrow r_z] \longrightarrow s_w\} \longrightarrow \text{etc.} \equiv pqrs \ldots 1^n_{xyzw\ldots} \ldots (1a)$$

in which $pqrs\ldots$ is merely scalar,[1] and n, the number of factors is equal to the number of suffixes; that is to say, n is the number of dimensions.

5. *General laws of fluxional generation.*—From what has preceded it is evident that an n-dimensional geometrical figure can be generated, by a single motion into the nth dimension, of an $(n-1)$-dimensional figure, by two *successive* motions of an $(n-2)$ dimensional figure, one being in the direction of the $(n-1)$ the axis, and the other in that of the n-th axis of the higher spaces; and similarly by a greater number of specifically-different *successive* motions, when the generatrix is of lower dimension. It is further evident that, at least in homaloidal space, the relative order of the generative motions is immaterial.

The results may be presented in the following form:—

A geometrical figure of n dimensions can be generated by k successive[2] motions or displacements of a generatrix of $(n-k)$ dimensions, parallel to k independent axes, *not included in the space-axes of the generatrix.*

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as already shewn, not an absolute zero. If such a zero had no duration, an infinity of such could not be conceived as implying duration at all. More crudely, infinitesimal motion may be apprehended as the *incipience of motion*, the state of the generatrix at the instant of commencing to move, or rather during the infinitesimally small time when it commences to move.

[1] A scalar, or vector "divided by" a parallel vector is a purely abstract number, a mere *ratio*, px is to be understood as $p \times 1_x$, where 1_x is the vector unit, and p is an abstract number or a scalar. As scalars have no spatial properties, pqr etc. or xyz etc. have no other essential meaning than that they are the product of abstract numbers.

[2] It is essential that the motions be successive, and not simultaneous: a point for example moving in the direct x and y generates a line instead of the surface xy: it is the *path* x, moving the distance y, or the *path* y, moving the distance x, that generates the surface.

In homaloidal space the order of succession in the generative operations is indifferent, that is to say they are subject to the law of commutation.

6. *Inverse fluxional generation and its laws.*—The reduction of n-dimensional to $(n-k)$ dimensional figures may be called *inverse generation*. Its scheme may be represented by

$$\{[(pqrs\, 1^4_{xyzw}) \leftarrow\!\!- s_w] \leftarrow\!\!- r_z\} \leftarrow\!\!- q_y \equiv p_x \ldots\ldots\ldots (2)$$

the inverse operator $\leftarrow\!\!-$ denoting that the operation is reductive.

It is evident therefore that:—A geometrical figure of n dimensions can be reduced to one of $(n-k)$ dimensions, by k successive motions or displacements, of the generatrices of $n-1$, $n-2 \ldots n-k$ dimensions in directions inversely parallel to those by which it was or could be generated.

In homaloidal space the order of reduction is indifferent: that is to say the inverse operations are (also) subject to the law of commutation. These two propositions are merely the obvious inverse of the preceding ones.

7. *Zeros and infinities of* n-*dimensions.*—The conception of n-dimensional numerical zeros and infinities is an essential in the logical use[1] of any infinitesimal calculus, and as we have seen is immediately given by the consideration of spatial dimensions, as illustrated in (1), § 3. Though the matter has been the subject of some controversy, it is susceptible of perfectly rigorous exposition, as may be thus demonstrated[2]:—

[1] This cannot be said of the formal use of such calculus. If a curve $y=f(x)$ were conceived to consist of points separated a 1st order infinitesimal distance, the line joining any pair makes the angle $\theta = \tan^{-1} dy/dx$ with the axis x if the axes are orthogonal, which is sufficient for questions not affecting the deviations of the curve from this direction when second order infinitesimal distances are taken into account. The changes of θ are $d\theta/dx$ in the former case and $d^2\theta/dx^2$ in the latter. This point will be considered later.

[2] Much confusion on the conceptual character of zeros and infinities from a popular impression that they cannot be distinguished, since, it is thought, all relations between quantities must disappear at the point at which they vanish into nothingness, or when they transcend, as it is supposed, our powers of representation. But as has, and will be further shewn, zeros and infinities of various kinds are conceptual entities and are not without conceptual properties. To meet the difficulty indicated

A linear unit divided into m parts may be reconstituted by m elements of length $1/m$; a surface unit, each unit side of which is divided into m parts, by m^2 elements of surface-area each $1^2/m^2$; and similarly a unit quantum of n dimensions, may be made up of m^n elements, each of $1^n/m^n$ quantum.[1] If now zero be defined as unity divided by infinity, that is if zeros and infinities are pure *reciprocals*, viz.

$$0^n \equiv \frac{1^n}{\infty^n};\ 1^n \equiv 0^n\,\infty^n;\ \infty^n \equiv \frac{1^n}{0^n};\ \text{etc.}\ldots(3),$$

where n may have any value whatever. Making m infinite the index and dimension are throughout identical, that is to say, we must admit the relations :—

$$0^n_n \equiv \frac{1^n_n}{\infty^n};\ 1^n_n \equiv \frac{1^n_n}{1^n};\ \infty^n_n \equiv \frac{1^n_n}{0^n};\ \text{etc.}\ldots(3a)$$

The purely numerical relationships of n-dimensional zeros, of zero-value in each dimension, absolutely involves the admission of the idea of different *orders* of *numerical* zero, infinity, etc., as conceptually necessary; in fact no less necessary than that of a first order infinity. Apart however from the mere numerical development implied in spatial relationships, the ordinary *linear* conceptions involve at least two orders of infinity, for a finite line is conceptually admitted to be capable of subdivision into infinitely small parts, and on the other hand to increase to infinity. Consequently $x = dx,\ = 1,\ = \infty$ imply a range of ∞^2 at least.[2] Once

the doctrine of *limits* has been developed, in which the object of study has been the relation of quantities at the point of their evanescence, or on the other hand when they become infinitely great. There is no escape from the conception of the differential, and the doctrine of limits does not materially avoid this particular difficulty. Certain writers, *e.g.* Todhunter, see his Differential Calculus, Art. 26, treat the differential fraction expressing the ratio of quantities at the point of evanishing, as a "*whole*," instead of as the real ratio of actual infinitesimals, or 'indivisibles.' That is to say dy/dx is not to be regarded as a real relation between the zero quantity dy and the zero dx, but as an undecomposable *ratio* representing the limit of their real ratios at the point of vanishing of the quantities themselves. This introduces logical difficulty, when afterwards we find dx and dy on opposite sides of an equation, or when we are to integrate say $f(x)dx$.

[1] The use of an index with unity defines its dimension.

[2] In fact $dx/x = x/\infty x$, that is to say where the infinitesimal and infinite are admitted as concepts *at all*, the commonest conception involves at least a second order of linear infinity.

the difficulty even in linear quantities of conceiving an infinity of infinities is transcended, there can be no further conceptual difficulty in admitting infinities of any orders. A similar remark applies to zeros of any order.

8. *Summational generation by means of the* n-*dimensional point.* —The essential difference between mere multiplication, of a geometrical infinitesimal of any dimension, by an abstract number, and the apparent numerical identity of essentially different operations upon the dimensionless point, may be elucidated by regarding inductively, the developments conceivable in successive dimensions of space. Assuming a series of axes x, y, z, w, etc., not necessarily orthogonal, let first an infinite number of linear zeros be taken having dimension in the direction x only. These may be summed in two ways, (a) by addition along the axis x, (b) by addition in the direction y. In the former case we get as result 1_x, in the latter 0_x, since they are dimensionless in the direction y. If further ∞^2 of these zeros be taken, we get ∞_x by the former addition, and still only 0_x by the latter. Suppose, however, we start with an infinite number of 2-dimensional zeros, 0^2_{xy}. Addition along the axis x gives 1_x, along y, gives 1_y, the resultant lines not being *purely* linear, but fully represented by the surface symbols $1_x0_y \equiv 0^1_{xy}$; $1_y0_x \equiv 0^1_{yx} = 0^1_{xy}$; that is we obtain a line 1_x of infinitesimal breadth 0_y, or a line 1_y of breadth 0_x. It is also a surface *zero*, but one that is infinitely greater than 0_x0_y, that is to say, $\infty\, 0^2_{xy} = 0^1_{xy}$. With such infinitesimals as these, any surface can be generated summationally, but only by operating in the xy plane. Thus an infinite number of 1_x0_y units by addition along the x axis give ∞_x0_y an infinite line of infinitesimal breadth, by addition along the y axis 1_x1_y *i.e.* 1^2_{xy} or a unit of surface, and *vice versa* for 1_y0_x. Addition in the direction of the z axis produces no result whatever, because these elements are dimensionless in that direction. Thus we may state with generality that :—

All summational operations with infinitesimals are significant only for axial directions corresponding with their dimensions, but not otherwise.

No quantity can be generated in the $(m+1)$th dimension by summational operations on quantities of the mth dimension.

It is now evident that with infinitesimals of the nth dimension, defined by $0^n_{xyzw..etc.}$, the summational operations may be *wholly restricted to any lower dimension*, or on the other hand, *may develope in any order*, through the series of axial directions up to and inclusive of the n-th dimension itself, *but not beyond it.* Remembering that the several axes may be interchanged, the following series of symbols will sufficiently indicate the successive developments by means of infinite summation of the 1st, 2nd, and 3rd and 4th orders. We take as generatrix a 4th dimensional infinitesimal, the various developmental forms of which are shewn in the first line, and the sum to ∞, ∞^2 etc. in the successive lines downwards.

Magnitudes of Generated Quanta.

$$\left.\begin{array}{cccccccccc}
\text{Order of Summation.} & (1) & & (2) & & (3) & & (4) & \\
1 & 0^1_x 0^3_{yzw} & = & 0^2_{xy} 0^2_{zw} & = & 0^3_{xyz} 0^1_w & = & 0^4_{xyzw} & \text{etc.} \\
\infty & 1_x 0^3_{yzw} & = & 0^1_{xy} 0^2_{zw} & = & 0^2_{xyz} 0^1_w & = & 0^3_{xyzw} & \text{etc.} \\
\infty^2 & \infty^2_x 0^3_{yzw} & = & 1^2_{xy} 0^2_{zw} & = & 0^1_{xyz} 0^1_w & = & 0^2_{xyzw} & \text{etc.} \\
\infty^3 & \infty^2_x 0^3_{yzw} & = & \infty_{xy} 0^2_{zw} & = & 1^3_{xyz} 0^1_w & = & 0^1_{xyzw} & \text{etc.} \\
\infty^4 & \infty^3_x 0^3_{yzw} & = & \infty^2_{xy} 0^2_{zw} & = & \infty_{xyz} 0^1_w & = & 1^4_{xyzw} & \text{etc.} \\
\text{etc.} & \text{etc.} & & \text{etc.} & & \text{etc.} & & \text{etc.} &
\end{array}\right\}\ldots(4)$$

It will be noticed that numerically $0^1_n \equiv 0.1^{n-1}$ or more generally $0^k_n \equiv 0^k 1^{n-k}$. Let the generated quanta be denoted by

$$\begin{array}{cccc}
a & e & i & m \\
b & f & j & n \\
c & g & k & o \\
d & h & l & p
\end{array}$$

they may be described as follows:—*Linear elements*, (a) a linear unit; (b) and infinite line, (c) an infinite line of the second order;[1] (d) and infinite line of the third order. *Surface elements*, (e) a linear surface-zero, that is such as zero as would be represented by the parallelogram $1_x 0_y$; (f) a parallelogrammic surface unit;[2]

[1] That is a line such that its unit is an infinity of the first order, and its zero-element a unit of the first order.

[2] If the axes are orthogonal, substitute "rectangular" for "parallelogrammic": if the units are also equal substitute "square."

(*g*) a surface of infinite length the other dimension being unity; (*h*) a surface infinite in both dimensions. *Volume elements*, (*i*) a linear volume-zero, *i e.* $1_x 0_y 0_z$; (*j*) a surface volume-zero, *i.e.* $1^2_{xy} 0_z$; (*k*) a parallelepipedic unit volume[1]; (*l*) a volume of infinite length but of parallelogrammic unit dimensions. *4th dimensional elements*, (*m*) a linear 4th dimensional zero, (*n*) a surface 4th dimensional-zero, *i.e.* $1^2_{xy} 0^2_{zw}$; (*o*) a volume 4th dimensional-zero, *i.e.* $1^3_{xyz} 0_w$; (*p*) an orthogonal or oblique 4th dimensional *quantum*, according as the axes are orthogonal or oblique. Throughout the series (4) the division has been made in such a manner as to shew that the equivalence (horizontally) is dependent upon the extension of the several quantities infinitesimally into the higher dimensions, if the generated forms are to be continuous.

9. *Zeros and infinities of successive orders.*—The scheme of summational generation outlined, indicates that in rigorous mathematical thought, the conception of different orders of infinitesimals and of infinities[2] is essential, not merely as a purely formal numerical artifice, but as really representing the developmental or generative processes, without which conceptual continuity of geometrical figures would not be a possibility, Hence linear, surface, and volume infinities, etc., are properly distinguished as to their dimensions and also as to their powers. To develope the unit of any *n*-dimensional quantity[3] from its proper zero, *i.e.* from the zero which is (a first order) infinitesimal in every dimension, it is necessary to *multiply* not merely by infinity but by the *n*th *order* of infinity, that is to say, as in (3*a*)

$$0^n_n \times \infty^n \equiv 1^n_n$$

[1] If axes are orthogonal, and units are also equal, substitute "cubic" for "parallelepipedic."

[2] According to Riemann, (*op. cit.*, Cap. 3, § 3, see Nature VIII., p. 36) questions about the infinitely great are useless in respect of the interpretation of Nature, *but not questions about the infinitely small.* Once it is admitted, however, that we are compelled to deal with a greater range than $0-1-\infty$ viz. $0^n - 1^n - \infty^n$ such a statement is logically defenceless, because magnitude is essentially *relative.* The interpretation of the infinitely great may sometimes be difficult, but that does not justify the dictum.

[3] Or *n*-ply extended magnitude. See Riemann's treatise, *op. cit.* Cap. 1, § 1.

Inasmuch as an n-dimensional unit can be divided by an infinity of the nth order, and as, moreover, scale-differences do not conceptually limit our thought, there is no conceptual limitation to a similar *division* of any infinitesimal or zero quantity.[1] Hence numerically, the quantities of ordinary mathematical conceptions range at least between

$$0^1,\ 1^1,\ \infty^1 \text{ and } 0^\infty,\ 1^\infty,\ \infty^\infty,$$

or, for ordinary tridimensional space, the higher limit must be at least 0^3, 1^3, ∞^3, and it is now easy to see this last is only an *artificial* restriction.

10. *Spatial continuity and its numerical expression.*—Although, as has been shewn, it is logically essential to distinguish between a dimensionless point and an infinitesimal of any dimension, it is possible to employ the former in a perfectly definite and rigorous manner to define the development of geometrical figures; that is to say the dimensionless point may be taken as a *sign* or mark of the infinitesimal, its *locus* in space being to the first order of infinitesimal identical therewith, but not exhaustively so.[2]

Space being essentially a *continuum*, and a *plenum*, the substitution of dimensionless and therefore discrete points, in a mere numerical scheme for determining its *quanta*, *i.e.* portions marked

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[1] Or we may realise the inherent simplicity of the conception in this way:—We have no difficulty in conceiving that a finite line is a *singly-infinite continuous series or group* of infinitesimal lines; a finite plane area, is a *doubly infinite continuous group* of infinitesimal areas; a finite volume is a *triply infinite continuous group* of infinitesimal volumes; and generally a finite quantity of the nth dimension is an n-*ply infinite continuous group* of an infinitesimal of n-dimensions. Since these facts are *numerically* representable, there is no conceptual difficulty in extending our conception of infinity and infinitesimals to the higher orders of such quantities, hence 0^n, ∞^n represent not merely numerical abstractions, but real ideas.

[2] This may be pictured as the point occupying the centre of the infinitesimal, which latter, in relation to it, can be regarded, loosely of course, as absolutely infinite. In Cayley's expositions of higher geometry, (*e.g.* the "Sixth Memoir on Quantics," Phil. Trans. Vol. 149, 1859, pp. 61 – 90) and in Henrici's, the geometry is essentially discrete point geometry, and a *row, range*, or *assemblage* of points is distinguishable from the base, or line, surface etc., in which they lie, only when account is taken of higher orders of infinitesimals. Thus the equation, $(\ast \between x, y)^m = 0$ may be variously interpreted, as soon as account is taken of the nature of the zero.

off by *boundaries*, does not *necessarily* imply discontinuity.[1] The point relations corresponding to (4) become simply

Magnitudes of Generated Quanta.

$$\left.\begin{array}{cccccc}
\text{Summation.} & (1) & (2) & (3) & (4) & \text{etc.} \\
1 & 0^1 & 0^2 & 0^3 & 0^4 & \text{etc.} \\
\infty & 1^1 & 0^1 & 0^2 & 0^3 & \text{etc.} \\
\infty^2 & \infty^1 & 1^2 & 0^1 & 0^2 & \text{etc.} \\
\infty^3 & \infty^2 & \infty^1 & 1^3 & 0^1 & \text{etc.} \\
\infty^4 & \infty^3 & \infty^2 & \infty^1 & 1^4 & \text{etc.}
\end{array}\right\}\ldots(5)$$
$$\begin{array}{ccccc}\text{etc.} & \text{etc.} & \text{etc.} & \text{etc.} & \text{etc.}\end{array}$$

which completely defines the purely *numerical relationships of different dimensions*, their infinities and infinitesimals. That mere *numerical* analyses of spatial properties are liable to lead to erroneous conclusions, is obvious on comparing (5) with (4). Thus if with Helmholtz, Lie, Poincaré, etc., we define the matter of ordinary geometry a 'numerical multiplicity' or 'manifoldness' *(Zahlenmannigfaltigkeit)*[2] of three dimensions, it ought to be understood that this applies only to its *formal* or purely numerical representation, and not to its spatial properties which are to be interpreted therefrom.

In order to guard against erroneous deductions, this distinction between spatial quantities and mere numbers, *i.e.* between vectors, rotors, etc., and scalars and abstract numbers generally, should be carefully preserved.

Remembering that the geometrical figure 1^4_{xyzw} may be completely written 1^4_4 whenever the particular axes do not need specification, the *quanta* X, Y, Z, W,...N, of regular figures, parallelograms, parallelepipeds, etc., whose sides parallel to the several axes may be expressed by the numbers x, y, z, w...etc.,

[1] Riemann distinguishes between *continuous* or *discrete* manifoldness, calling the spatial specialisations of the former *points*, and of the latter *elements*; *Op. cit.* 1, § 1. In English is not the reverse use preferable? A *discrete* manifold is strictly not space, but a distribution in space.

[2] In general, number imperfectly represents quantity. The science of *number*, says Clifford, is founded on the hypothesis of the distinctness of things; but the science ot quantity on the totally different hypothesis of continuity. Lectures 1, 337.

meaning however $x.1_x$, $y.1_y$, etc., are fully defined by writing them,

$$X \equiv 1_1^1 x;\ Y \equiv 1_2^2 xy;\ Z \equiv 1_3^3 xyz; \ldots N \equiv 1_n^n xyzw \ldots \text{etc.} \ldots\ldots (6)$$

that is to say, $xyzw$ etc. is a mere *scalar product*, and the linear, square, cubic, quartic, n^{ic} value of $X, Y, Z, W \ldots N$, depends *wholly* upon the value of the unit quantities 1_1^1, 1_n^n, etc.[1]

Thus it is quite immaterial whether the units parallel to the axes x, y, z etc. are unequal or equal. If the former, and measured by some common linear unit they are a, b, c, d etc., and if also the axes instead of being orthogonal differ from $\frac{1}{2}\pi$ by the amounts ϕ, χ, ψ, ω, etc., then in orthogonal n-dimensional units, coinciding with that by which a, b, etc. are measured,

$$1_n^n = (abcd \ldots)(\cos\phi \cos\chi \cos\psi \cos\omega \ldots) \ldots\ldots (6a)$$

Hence obviously the numerical representation of space, and the spatial interpretation of numerical values ought logically to be kept distinct.

We observe also that the ordinary loose way of writing $m0 = 0$, $m/\infty = 0$, $0/0$ etc., makes operation upon such quantities subject to uncertainty, and further that $\infty 0$ is unity,[2] only for equivalent dimensions, since

$$0_n^n \times \infty = 0_n^{n-1};\ 0_n^n \times \infty^m = 0_m^{n-m} \ldots\ldots (7)$$

No uncertainty can arise so long as scalar and vector parts of each operation, are carefully distinguished, and the real magnitudes of zero and infinities are retained.

11. *Rotational generation.*—Generation by rotations, or by rotation combined with axial motion, does not essentially differ from the latter alone, and is of course continuous, n-dimensional figures will of course, be generated by motion of an $(n-1)$-dimensional generatrix whenever it moves into the n-th dimension. The total number of ways in which generative motion can take place, may be enumerated as follows, viz.:—

---

[1] In practice the index and suffix are of course not required, because the number of axes x, y, z etc. denotes both at the same time. Because in pure numbers $1 \times 1 \times \ldots 1$ to n figures can be represented only by 1, we are apt to forget that 1^1 and 1^n may be very different quantities.

[2] See Chrystal, Text Book of Algebra, II., pp. 66 – 96, 1889.

$$\left.\begin{array}{lcccc}
\text{Dimensions} & (1) & (2) & (3) & (4) \\
\text{Axial motions} & x & x, y & x, y, z & x, y, z, w \\
\text{Rotations in the planes} & 0 & xy & xy, xz & xy, xz, xw \\
 & & & yz & yz, zw \\
 & & & & zw \\
\hline
\text{Total } \tfrac{1}{2}n(n+1) \quad = & 1, & 3, & 6, & 10
\end{array}\right\}\ldots(8)$$

that is to say the number of *degrees of freedom* of movement for n-dimensional space is evidently $\frac{1}{2}n(+1)$, or, what is the same thing, each dimension increases the number of degrees of freedom by the number which expresses the dimension itself. To consider the point as the geometrical entity of dimension 0, is obviously consistent with this formula. The matter of this special form of generation, however, calls for no comment since it differs from that previously considered, only in regard to the figure of the element, and to the mere characteristics of the generative scheme, and not essentially.

12. *Finitely and absolutely homaloidal 2-dimensional space.*—Consider the expression

$$xy = a \ldots\ldots\ldots (9)$$

in which a may have any positive or negative value from $-\infty^n$ to $+\infty^n$. If in (9) xy denote a purely abstract product, and a an abstract number also, the equation implies a purely numerical relationship, between the three quantities, and one that, *per se*, is independent therefore of all questions as to a possible geometrical interpretation or significance. As such, that is as a purely numerical relationship, we notice that the scale of *either* x or y can be increased m times, or both can be equally increased $\sqrt{m}$ times, by multiplying a by m, or both can be increased m times by multiplying by m^2. Hence there is no essential difference, excepting one of *scale*, in any uniform scheme of geometrical interpretation of this expression, *i.e.* (9). For example, if the values of a be 0^1, 0^2,...0^n the reciprocal relations of x and y are completely defined by—

$$
\begin{array}{lllll}
\text{Values of } a = +0^1 & & +0^2 & & +0^n \\
\text{Value of } x \text{ or } y. & & \text{Values of } y \text{ or } x. & & \\
\infty^n & \mp 0^{n+1} & \mp 0^{n+2} & \ldots & \mp 0^{2n} \\
\infty & 0^2 & 0^3 & \ldots & 0^{n+1} \\
1 & 0^1 & 0^2 & \ldots & 0^n \\
0^1 & 0^\circ = 1 & 0^1 & \ldots & 0^{n-1} \\
0^2 & 0^{-1} = \infty & 0^\circ = 1 & \ldots & 0^{n-2} \\
\ldots & \ldots & \ldots & \ldots & \ldots \\
0^n & 0^{-n+1} = \infty^{n-1} & 0^{-n+2} = \infty^{n-2} & \ldots & 0^\circ = 1
\end{array}
\quad \ldots(10)
$$

Passing now to a geometrical interpretation, if x and y are vectors, *i.e.* quantities parallel to two axes, whether orthogonal or inclined is immaterial,[1] we may observe that if (9) be understood as defining the dependence of y upon x and a, *i.e.* if it signify that $y = a/x$, then, the path P, traced by one terminal of the line y as its other terminal moves continuously along the x-axis from $-\infty$ to $+\infty$, departs from that axis amounts which depend upon the orders of infinity and zero. Thus if $a = 0^2$, which is the normal form for $x = 0^1$, $y = 0^1$, it will be noticed that $y = 0^1$ for $x = 0^1$; while for $x = 0^2, 0^3$, $y = 1, \infty$. Similarly if a be infinitely greater than 0^2, *i.e.* if it be 0^1, then the value of y is a first order infinitesimal from $x = -1$ to $x = -(0^1 + \delta x)$ and at 0^1 becomes -1. For $x = +0^1$, $y = +1$, and for $+(0^1 + \delta x)$ a first order infinitesimal as far as $x = +1$, reducing to a second order infinitesimal for $x = \infty$. If conceptually we *slur* over the passing from -0^1 to $+0^1$ as *insignificant*, we lose sight of the extension of the *discontinuity* from $-1, +1$, to $-\infty^n, +\infty^n$. The defect in continuity of a discrete point geometry, leaves therefore certain possibilities of interpretation unrevealed. If $a = 0^2$ be multiplied by ∞^2, it will become 1, which is equivalent to enlarging the scale infinitely in both dimensions. The *graph* then becomes two opposite hyperbolas, equilateral if the axes are orthogonal. The results for different values of x from plus to minus infinity of the first order, and slurring over the first order infinitesimals -0^1 to $+0^1$, are

$$y = \; -0^1 \;\; -1 \;\; -\infty \;\; +\infty \;\; +1 \;\; +0^1$$

that is the discontinuity is from minus to plus infinity. If how-

[1] The axis may also be curved or straight, provided "parallel" is suitably defined.

ever the higher orders of infinities and infinitesimals be considered, the zeros and infinities become also of higher order, and the discontinuity correspondingly augmented.

The importance therefore of distinguishing between the dimensionless point, and the infinitesimal of any dimension, and also the necessity of admitting the conception of different orders of infinitesimals and infinities now more fully appears.[1] The matter may be brought into a still clearer light by observing that if we regard the x-axis as a mere *assemblage* of points separated by infinitesimal distances of the first order, and the y terminals as the corresponding or *dependent assemblage* P, then the graph of $xy = 0^2$, is to the first order infinitesimal *undistinguishable from the* x*-axis itself.* But if we interpolate between this assemblage a second infinite series, *this is no longer true.* The conception of *absolute continuity,* requires that there be no limit to this interpolative process; hence, if x vary in an *absolutely* continuous manner, viz., in the way an absolutely dimensionless point may be conceived as moving upon or generating a line, then it follows that the surface necessary to completely define the graph must admit of *absolute extension,* for the order of the infinity, must coincide with the order of the infinitesimal. Conceptual space[2] is subject to no limits except those which limit the operation of human thought, and hence the "dreary infinities of homaloidal space,"[3] must include the concept of what may be called *pure* homaloidal space, viz.,

---

[1] And the significance of successive differentiation is correspondingly enhanced.

[2] It is remarkable to find the phrase the 'space of experience' employed as if it were a *thing* to be investigated, instead of an *a priori* concept in terms of which we are obliged to *explain* phænomena. This is a matter which we shall further discuss. See Whitehead, Universal Algebra, Vol. I., footnote p. 499.

[3] Clifford, Lectures and Essays, Vol. I., pp. 322-3, Mathematical Works xlvi. *Pure* homaloidal space, may be popularly defined as that in which a point travelling rectilinearly never returns upon its path. Imagine two points so moving, one vastly faster than the other. Then in infinite time, the journey of the faster would be vastly greater than that of the more slowly moving point; if infinitely faster, then though the first point would have travelled an infinite distance the latter would have travelled an infinity of such infinities. Conceptually there is no limit to the "dreary infinities" of such space.

that which is *absolutely homaloidal*, or at least homaloidal to an infinite order of infinity. We may call a surface that is plane for finite geometrical figures, but not for their infinite enlargement, *finitely homaloidal*, and since such a surface must be infinite, it is a finitely-homaloidal infinite surface.

Similarly a surface homaloidal for geometrical figures of infinite magnitude may be described as *homaloidal to infinity of the first order*. These may be defined as an homaloid of the 1st order and of 2 dimensions; and of the 2nd order, of 2 dimensions.

13. *Resolution of discontinuities in 2-dimensional curves, through infinite paths in 3-dimensional space.*—In absolutely homaloidal (conceptual) space every point on a straight line divides it, as we have seen, into absolutely infinite branches, which are consequently absolutely discontinuous.

If at a point A, on the straight line, a tangent circle of infinite radius[1] be drawn, the deflection δy say, of a point B on the line, distant x from A is

$$\delta y = \tfrac{1}{2}\,0^1x^2 + \tfrac{1}{8}\,0^3x^4 + \text{ etc.} \ldots\ldots\ldots (11)$$

which is zero[2] for all *finite* values of x, it follows that every *finite* straight line may be regarded as the circumference of a circle of infinite radius, the centre of which circle, however, lies *indifferently* in any point of a circle of equal infinite radius, the locus of the possible centres being in a plane perpendicular to the line. The distinction consequently between $+\infty$ and $-\infty$ may either be regarded as generally evanescent, or at least as evanescent at the opposite or *antipodal* point on an infinite circle or infinite spherical surface, that is at least for figures of finite dimensions. *Schematically*, therefore, we can move a point along a line AB in two ways, either through the finite path, or the infinite one, the directions of motions being opposite[3]; or algebraically $+x \equiv -2\infty + x$, that

[1] First order infinity. [2] A first order zero.

[3] See Henrici, Article Geometry, Encyc. Brit. X., 389; also Luigi Cremona, Elements of Projective Geometry (trans. Leuesdorf) Chap. VIII. § 52, p. 44, 1885. Infinity is thus the total circle, hence its radius is symbolically $\infty/2\pi$.

is[1] $-2\infty \equiv 0 \equiv +2\infty$. That this is an essentially *artificial* representation[2] is evident from the following considerations, viz.: 1° The discontinuity is resolved through an infinite path of the first order, but cannot be resolved *within the dimension itself*. 2° Though it can be resolved in space of higher dimension, even that space has no unique position, since the circle of continuity may be anywhere on the surface of an infinite tore, see Fig. 1. 3° The *curvature is zero only for finite geometrical figures, and to the first order of infinitesimal*,[3] and is consequently distinguishable from the lesser curvature of linear "space" of a higher order of infinity.

This scheme of resolving infinite discontinuity can be extended to space of any dimensions by infinite *unbounded* figures of a higher dimension. Reverting to equation (9), if we put $a = 0^1$ and treat x as the independent and y as the dependent variable, we obtain the following values

$$x \pm \infty, \pm 0^2;\ y = \pm 0^2, \pm \infty$$

that is the equation represents two straight lines apparently[4] crossing one another at whatever angle x makes with the y axis. On a sphere of infinite radius (of the first order) and therefore of (first order) zero curvature, these may be represented as in Fig. 2, by the lines O′X′OY′O′YOXO′X′, developed in that order. The order and the resolution of the discontinuity, are better illustrated by the hyperbolas

$$xy = 1 \ldots\ldots\ldots (12),$$

shewn by the heavier lines with arrows indicating the direction of progression, the generation being $-$ to $+$. The lines are the locus P, the terminals of y, its distance from x continually satisfying (12). When the radius OC is finite, the curves will lie on opposite sides of the axes XOX′, YOY′, as shewn Fig. 2, but when it is infinite, they are distant only $0^1/4\pi$ from the axes; hence,

[1] 2∞ is sometimes regarded as the limit of the even numbers. See Wead, Some discontinuous and indeterminate functions. Phil. Soc. Washington, Bull. XIV., p. 66, 1900.

[2] That is a purely schematic representation always distinguishable from the rigorous representation.

[3] As may be seen by multiplying (11) by infinity.

[4] It will be seen that the y line *does not really cross* the x line.

rejecting any consideration of infinitesimals of the second order, both curves may be *supposed* to cross the axes at the point. In this view, the differences between + and −, may be so construed as to lose their significance when applied to infinity, and by this scheme four infinite discontinuities disappear and disclose a single pseudo-continuous curve, which in relation to other finite figures, at finite distances from the origin, fulfils the requirements of ordinary physical interpretations. There is of course no limit to the resolution of discontinuities of this type. For example the curve

$$y = \pm \sqrt{\left\{ \frac{x(x-1)(x-2)}{x+3} \right\}} \quad\ldots\ldots\ldots(13)$$

has six branches, represented in Fig. 3, forming on the infinite sphere a (pseudo) continuous line. On a spherical surface the discontinuity of the small oval figure—see Fig. 3*a*—from $x=0$ to $x=1$, remains unresolved. This however is resolvable on a different surface as will now be shewn.

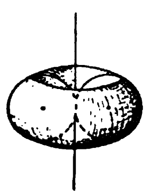
Fig 1

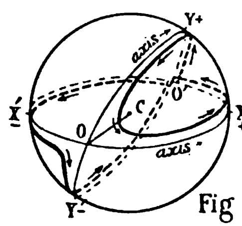

Fig 2

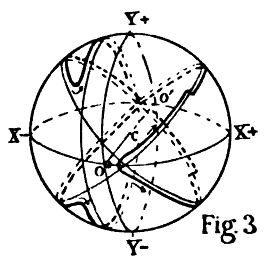

Fig 3

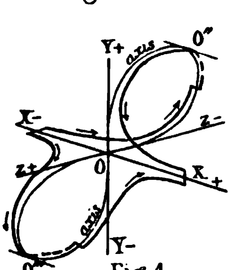

Fig.4

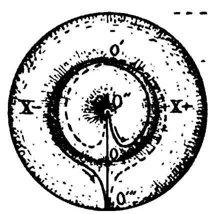

Fig.5

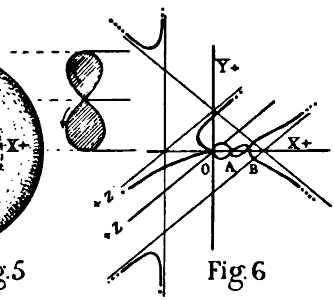

Fig 6

A curve of the type

$$xy^2 = 1\ldots\ldots\ldots(14)$$

y being the dependent variable, gives four hyperbolic curves, two

real for plus values of x, and two imaginary for minus values. If we take $z = iy$ perpendicular to the xy surface,[1] the several branches can be represented as continuous on what may be called a double *Cassinian tore*, or *lemniscate double-tore*, that is to say, two solid rings in contact and of such form that the section is a lemniscate. The polar equation of this section being $\rho^2 = \cos 2\theta$, gives two tangents perpendicular to one another, the axes y and z. Figures 4 and 5 shew the development of the surface. The plane of the lemniscate OO″O‴ contains the axes YY and ZZ, and the axis XX is perpendicular thereto. The positive branches lie in the surface xy and the negative in the surface xz.[2] The double toroidal surface will allow the previous curve, (13), to be also continuously represented, but its various branches will unite somewhat differently in order to include the imaginary parts of the curve; contrast Figs. 3 and 6. In the latter figure the curve, Z′ O etc., lies in the xz plane, as also does the curve from A to B. From O to A, and from B onward, the curve is in the xy plane. It will be noticed that the double toroidal surface requires the continuity to be established in the order shewn by the dots; Fig. 6.

By making the radius of the sphere, or the parameters of the curves, of a higher order of infinity, the continuity is developed to a higher order of infinitesimal, *and to this process there is no conceptual limit*, that is the pure plane is of absolute-zero-curvature, or rather, has no curvature at all.

14. *Infinitesimal approximation and absolute identity in differential coefficients.*—We have seen that the resolution of a discontinuity through infinite paths gives nothing more than pseudo-continuity, and that conceptually we can always recognise the purely formal and artificial nature of the continuity thus apparently attained. In practical applications the matter is of no moment,

[1] See § 33 hereinafter.

[2] In Fig. 5 one tore lies or fits within the other. In order that the infinities should be identical in magnitude, the loop of the lemniscate ought to be equal in length to the circle OXO′X, hence one must be above the other as in the shaded part of Fig. 5. It is easily shewn that the length of the loop is expressed by an elliptic integral of the first kind.

since the range from the first order infinitesimal to the first order infinity necessarily transcends practical requirements. In testing the conceptual validity of spatial theories however, these things are no longer unimportant. That the infinitesimal calculus affords a clear illustration of the essential difference between infinitesimal approximation and absolute identity, may be readily illustrated by considering the difference between a curve that is the path of a moving point, and one which is merely a range of discrete points. Let for example ξ and η denote the coordinates, with the same axial directions, of any point in the curve

$$y = a + bx + cx^2 + dx^3 + \text{etc}.\dots\dots\dots(15)$$

from some point x, y as origin, in the curve itself: then we shall have

$$\frac{\eta}{\xi} = B + C\xi + D\xi^2 + \text{ect}.\dots\dots\dots(16)$$

B being the differential coefficient of (15), C half the differential coefficient of B, etc.[1] If $\xi = 0^1$, the term $C0^1$ is an infinitesimal of the first order compared with B, and therefore has a value of which no numerical account can be taken, *so long as B is finitely expressed*, but has a finite value if the right hand member of (16) be multiplied by infinity, shewing that the tangent to the curve at the point $\xi = 0^1$ is not absolutely the true tangent at the origin, but really differs therefrom *infinitesimally*. The tangent at the point $\xi = 0^2$ evidently more closely approximates[2] to the tangent at the origin, since the C term is infinitely reduced. The difference is of course conceptual only, since it can only be expressed symbolically, and not numerically. Nevertheless once it is recognised that there is no escape from admitting different orders of infinity and therefore of infinitesimals, as conceptual entities, the distinction is not unimportant in discriminating what are really geometrical forms in space, and the space itself in which these forms are conceived to exist, and of which they constitute quanta.

The admission of higher orders of infinitesimals renders intelligible the conception, that although quantities may be reduced

[1] $B = dy/dx$; $C = \frac{1}{2!}\, d^2y/dx^2$; $D = \frac{1}{3!}\, d^3y/dx^3$; etc. [2] Is infinitely closer.

to zero of any particular order, yet to higher orders, the zeros have successive differences. Thus we realize that the *method of finite differences* leads to identical results with the infinitesimal methods, only because a *continuous* curve is supposed to be drawn through the successive points determined by the scheme of differences. When in equation (16), η/ξ becomes dy/dx, we see that the principle of continuity demands a recognition, that no matter how far the order of infinitesimal is carried back in the conception of differentiation, the infinitesimal stretch of the curve $ds = \sqrt{(dx^2 + dy^2)}$ approximately contains deviations from the chord, identical in character with that represented by the equation itself, but of course reduced in scale.

The same remark applies to curves of 'double curvature,' the continuity of tortuosity as well as of curvature, is conceptually carried back indefinitely.[1] We see therefore that a curve of discrete points, is essentially different from a continuous curve; and the chord drawn through two points infinitesimally distant, is clearly different from the tangent to the absolutely continuous curve through either, no matter what the order of the infinitesimal.

It may be said that the necessity for admitting an indefinitely great order of infinity will appear just as unequivocally, in the theory of metrics, of projective distance, of curved surfaces, and of parallels. We shall now refer to these.

15. *The theory of metrics.*—By von Staudt's theorem,[2] all quadrilaterals KLMN in planes containing the line or *range* ACBD, so constructed that pairs of opposite sides, KL, MN, shall meet in the point A, while the other pairs of opposite sides LM, KN shall meet in B, and the diagonals KM shall pass through C, will

[1] A curve of any character may be regarded as a *one-dimensional* region or 'space,' defined in relation to other spatial elements by its equation: treating it as a closed region can lead to no defect in mere physical applications, if the path be infinite. To treat plus and minus infinity as identical is none the less mere artifice, and it is only in the artificial sense, that "a one-dimensional region is to be conceived as a closed region, such that two elements divide it into two parts." See Whitehead, Universal Algebra, Vol. I., p. 168.

[2] Geometrie der Lage, Art 93.

have their remaining diagonals LN so determined as to pass through the one point D, see Fig. 7. These points ABCD taken in that order are called an *harmonic range*,[1] and the cross- or *anharmonic ratio*[2] thereof, viz.,

$$AC/BC \ : \ AD/BD = (ABCD) = -1 \ldots\ldots (17)$$

that is to say the anharmonic ratio of four harmonic elements is always -1.[3] An harmonic range possesses the property that if it be projected through any point S on to any other straight line, the projection A′B′C′D′ will also be harmonic; (Fig 7.). If A″B″C″D″ be drawn *absolutely* parallel to DS, DS will never meet A″C″: or as it is usually put, it will 'meet at infinity.'[4] If AC be a unit distance, $+1$, A being the origin, and AC = CB, then D will be 'at infinity,' the anharmonic (or cross-) ratio being

$$1/-1 \ : \ \infty/(\infty - 2) = -1 + \frac{2}{\infty} + \text{etc} \ldots\ldots\ldots (18)$$

Thus for a first order infinity the anharmonic ratio would *differ infinitesimally* from -1; and it cannot have the value -1 even if the infinity is *absolute*. Geometrically this may be illustrated by drawing A″C″ = B″C″ = 1, and the line C″D″ being ∞^n, the defect from parallelism is the infinitesimal angle, say $2/\infty^n$, of the same order as the infinity. Hence NL is always inclined to AD by infinitesimal angles, and D can *never* be indifferently on either side of C, as is generally assumed. This result may be stated in another form. Let O be a point midway between A and B so that $OA = -1$; $OB = +1$. As C approaches O, the harmonically related point D moves away from B, in such a manner that $OD.OC = 1$. For let $OD = x$, and $OC = \xi$, then (17) may be written

$$\frac{1+\xi}{-1+\xi} : \frac{x+1}{x-1} = -1, \text{ whence}$$

$$x\xi = 1^2 \ldots\ldots\ldots (19)$$

[1] And are determined by the symbol (ABCD). Möbius, Barycentrische Calcul, § 183. If two circles cut one another orthogonally any diameter of either is divided harmonically. Poncelet, Traité des propriétés projéctives, Art. 79. Paris, 1822.

[2] Clifford and Henrici prefer the term "cross-ratio" to Chasles' term anharmonic ratio.

[3] Möbius, *loc. cit.*

[4] That is never in an absolutely homaloidal space.

the same type of equation as (12).[1] The points C and D are *conjugate*, with respect to the *origin* O and the unit distance OB, and the distances OC and OD are *reciprocals*. As the point C moves from B, *i.e.* $+1$, through the origin O to A, *i.e.* -1, the conjugate point D moves from $+\infty$ to $-\infty$. This is the basis of the rectilinear system of *metrics*, that is a system which can be developed by drawing straight lines only, and it is immediately evident from Fig. 7 that a line of any definite ratio to the unit OB, can be so found.

The anharmonic ratio of *any* range of four points, (ABCD), is unaffected by projection,[2] consequently if two ranges each of four points are projective they are *equianharmonic*,[3] and hence if three collinear points A, B, C, are given, a fourth D may be found such that the anharmonic ratio of the range ABCD shall be any given number λ either positive or negative.[4] The *conjugacy* of points in an harmonic range, and the anharmonic ratio, are the foundation of the theory of distance, to which we shall later refer; the conjugacy however can be otherwise established, consequently a system of metrics and therefore a theory of distance can be founded *without* recourse to the anharmonic ratio, we shall see that conjugate points are determined by the rotation of a circle round a point on its circumference, the circle having a fixed tangent opposite the point of rotation: the intersections of the circle and the antipodal tangent with a line through the centre of rotation define the specified points. In Fig. 8 let the circles OCA″, OC′B″ rotate about the point O on the line D′OD. When the diameters of unit length A′O, OB′ are perpendicular to that line the point C is identical with O, as the circle rotates C and D move towards

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[1] Putting $OB = +a$, we get $x\xi = a^2$ not a. Therefore we write 1^2 not 1. When C is identical with B so also is D identical therewith, hence $x\xi = 1 \times 1$. The anharmonic ratio is an abstract number not a unit quantum.

[2] Pappus, Mathematicae Collectiones, Lib VII., prop. 129.

[3] Townsend, Modern Geometry, Art. 278. See also Steiner, Systematische Entwickelung der Abhängigkeit etc., p. 33, § 10, Berlin 1882.

[4] Chasles, Géométrie supérieure, p. 10, Paris 1852.

B, becoming identical therewith simultaneously. That O and D are conjugate, in respect of OB as unit length, is obvious, since if the angle A′OA″ = ODA″ = θ, and if the diameter of the circle be a, we shall have

$$OD = a \text{ cosec } \theta,\ OC = a \sin \theta;$$

hence, as before, denoting these quantities by x and ξ respectively

$$x\xi \equiv OD \,.\, OC \equiv a \text{ cosec } \theta \; a \sin \theta = a^2 \ldots\ldots (20)$$

the same equation as before, when a is unity.

Continuity as between plus and minus infinity may, in these examples, be variously represented and interpreted. Two illustrations will suffice. In Fig. 9, suppose the point C′ to move from A, (= − 1 from O) in the positive direction, the conjugate point D′ will move from A in the negative direction. When C′ is at the origin O, D′ may be conceived to be at the antipodal point[1] O′, as C″ continues to move towards B, D″ moves towards B from the antipodal point. The formal advantage of this is, that the double infinite discontinuity at the moment of crossing O is *apparently* resolved.[2] For a discrete point geometry, the points on the range being separated by zero distances of the first order, OO′ need be an infinity also of the first order only.

In obtaining D′ or D″ by construction, let the line ANM and the point N be fixed, then as C′ moves positively, the intersecting diagonals move continuously counterclockwise from the line NM to NB. Since the line NL_0 is parallel to AB it will 'meet it at $\pm\ \infty$,' hence the intersection by NL′ may, by a *fiction*, be considered as *beyond infinity*.[3] On an infinite spherical surface the line D′NL′ will intersect the line AOBO′ at the point antipodal to D′, that is *at infinity* therefrom, *hence that intersection is ignored;* and the second intersection, viz. at D′ (or the nearer intersection in the

[1] C_0 in the figure is the centre of the infinite sphere, whose diametral plane is D″OO′D′.

[2] If C″ continues, D″ moves towards O, reaching it when C″ reaches O′ and so on.

[3] The intersecting lines from N through B, D″ etc., moving clockwise, reach infinity when the moving point reaches O, moving from B, consequently the more divergent line may be conceived to intersect at a point *still further away*. This 'further away' however is not of the nature of a higher degree of infinity, *i.e.* it is not ∞^n.

direction L'N) is alone taken as the conjugate. The fact that the intersection antipodal to D' must be ignored, shews that the interpretation is purely formal and not without *inconsistency*.

The other method of resolving the discontinuity in determining the conjugate points C and D is illustrated in Figs. 10, 11 and 12. Let the circle OB be of unit diameter measured on the surface of an infinite sphere of which OO' is the *radius* and upon which it lies. Then since OB is finite and OO' infinite, B will be only infinitesimally distant from a sphere of which OO' is the *diameter*.[1] If the plane O'OB, Fig. 10, or O'OA″ Fig. 11, be made perpendicular to the plane O'AOB in either figure, the point C will be at O, and D at O″ Fig. 12; O'O″ being perpendicular to O'O. But the quadrant OEO″ is equal to the semicircle ODO', since any projection from O' through any point D to E makes the arcs OD, OE equal,[2] hence instead of regarding D as at O″, we may treat it as at O'. Similarly for any rotation θ from the vertical position, A'OA″, see Figs. 8, 10, 11, the real conjugate points should be C and E, but D may be substituted so long as the angle θ is measured at E, not at D.[3] For finite distances the error of this representation will be infinitesimal,[4] both in respect of the

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[1] And will be the greatest distance.

[2] We may call the curvilinear triangle ODE a curved isosceles triangle.

[3] The inclination of the planes may of course be measured at D: that inclination will be θ, see next footnote.

[4] Let the several angles be denoted by letters as follows:—

$$EOA'' = \tfrac{1}{2}\pi - \theta;\ OA''E = \tfrac{1}{2}\pi;\ OEA'' = \phi;\ OO'A'' = a;$$

OC $= \gamma$, measured on the sphere of which O' is the centre; OE $= \delta$; E being on the same sphere: then by spherical trigonometry

$$\cos\phi = \cos a \cos\theta = (1 - \frac{a^2}{2!} +)\cos\theta.$$

But a is a first order zero, hence $\cos\phi$ differs only infinitesimally from $\cos\theta$ for infinite distances. Again

$$\tan\delta = \tan a \operatorname{cosec}\theta$$
$$\tan\tfrac{1}{2}\gamma = \tan\tfrac{1}{2}a \sin\theta.$$

hence $$2\tan\tfrac{1}{2}\gamma\tan\delta = 2\tan\tfrac{1}{2}a\tan a.$$

Consequently $$\gamma\delta = a^2 + \tfrac{1}{12}(5a^4 - \delta\gamma^3 - 4\gamma\delta^3) + \text{etc.}$$

Taking the radius as infinity, this last is equivalent to

$$\xi x = a^2\left\{1 + \frac{0^2}{12}(5a^2 - c^2 - d^2) + \text{etc.}\right\}$$

which *so long as* d *is finite* can be only infinitesimally in error. The neglected terms are smaller still. Consequently the error of the scheme is infinitesimal.

angle at D and the distances OC and OD. Nevertheless the fact that the circle OA″C, Fig. 11, is not in absolute contact with

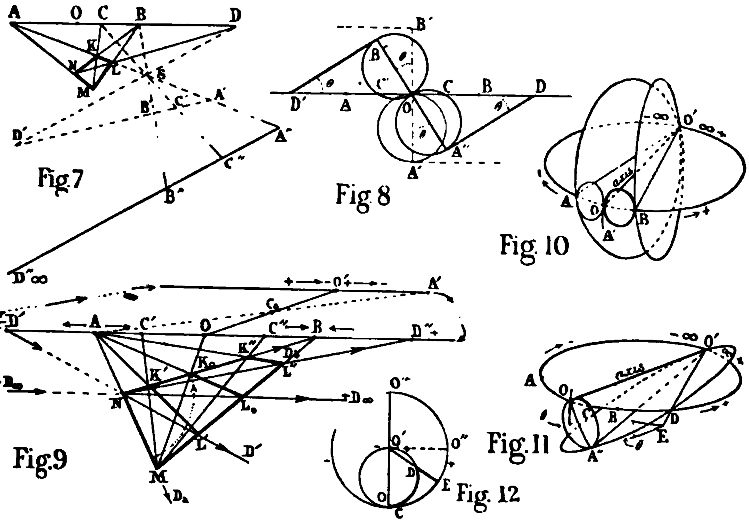


Fig. 7 Fig. 8 Fig. 10 Fig. 9 Fig. 11 Fig. 12

OBDO′, that the angle at E, and still more that at D, is infinitesimally in error, and that OC . OD is not absolutely equal to a^2 (or 1^2), sufficiently establishes the purely formal nature of the representation through which $+\infty$ and $-\infty$ are identified as spatially the same point. In essence it is equivalent to treating lines as parallel which meet at a sufficiently distant point.

16. *The projective theory of distance.*—In his "Sixth Memoir on Quantics,"[1] Cayley developed what is generally known as a "theory of distance," but what would be more readily understood if defined as "a projective theory of distance," that is a theory which applies not only to actual points in space, but also to their representation in projections.[2] This theory was extended, simplified, and its application to non-euclidean geometry pointed out by Klein.[3] The

[1] Phil. Trans., Vol. CXLIX., pp 61 – 90, 1859.

[2] Space may also be conceived to vary in what may be called its intensity: the theory of distance would apply with certain simple assumptions as to the law of variation of this intensity.

[3] Ueber die sogenannte nicht-euklidische Geometrie. Math. Amal., Bd. iv., 1871.

of the same order, or a surface whose radius of curvature is an infinity of higher order. The graphs of the two cases are pseudo-continuously represented in (*a*) and (*b*) respectively of Fig. 15, the ratio being represented on the y axes corresponding to any value of x.

The regions of impossibility indicate that the limitation of the definition of distance is identical with that which requires that we shall regard the operation of taking the logarithm of a negative number, as an impossible one.[1]

A curious result is that the 'distance' kl is infinitesimally near zero whatever the actual magnitude, if a and b be minus and plus infinity from k and l, or from l and k, since it is

$$D_{kl} = \log \rho_{kl} = \log\left(1 - \frac{2d}{\infty^n} \text{ etc.}\right) = -0^n \text{.........} (22)$$

d denoting the length kl.

The points a and b need not be real, but the case does not call for special consideration as regards the principle of continuity.

17. *The theory of linear intensity.*—It has already been noticed that the elements of projection lines are not necessarily uniform in their intensity. Consider in Fig. 14, the successive projection of the points r, q, p, a, n, b, it is obvious that no difficulty will be introduced by *assuming*, in tracing the correspondence from minus infinity (R) to plus infinity (B), that the progression commences at r and ends at b, the same point. This is of course purely schematic, for no consistent antipodal scheme of representation can be developed, (see Figs. 2, 9, 10, 11. 12). Nevertheless algebraically it will give consistent results for the intensity of the projected line. Defining, as before, *intensity* as the ratio of the real to the projected length, *i.e.* $I = \delta S / \delta s$, see Fig. 13, it may easily be shewn that if PS $= f$, S$b = g$ the angle of intersection BL$b = \phi$, and NS$b = \theta$, then the elements being infinitesimal, we shall have

$$I = \frac{dS}{ds} = \frac{f}{g} \cdot \frac{\sin^2(\phi + \theta)}{\sin^2 \theta} \text{.........} (23)$$

[1] It is easy to see that by changing the sign, or reforming the range, D_{kl} may have a real value.

Fig 13

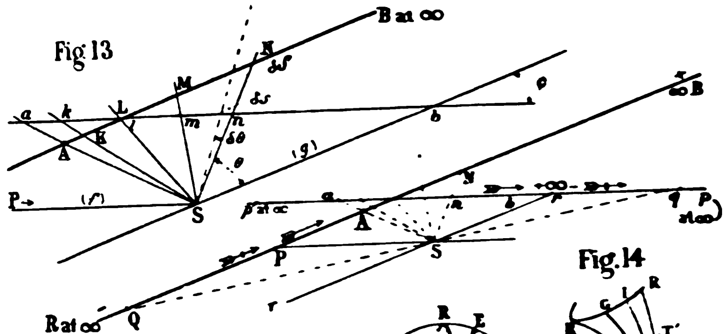
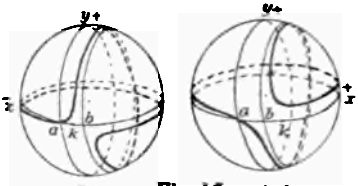


Fig. 14



(b) Fig. 15 (a)

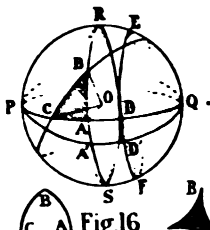


Fig. 16

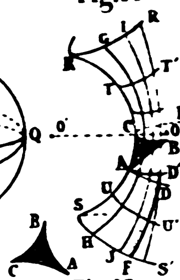


Fig. 17

hence for $\theta = 0°$ or $180°$, I is infinite; and when $\phi + \theta = 180°$ or $0°$, I is zero; the infinity and zero being of the same order. Again if f be zero, that is if S be infinitesimally close to the line RB, I becomes zero, for all finite values of ϕ and θ excluding zero; conversely if g be zero, f being finite, that is if S be infinitesimally close to the line ab, then I is infinite for all finite values of ϕ and θ excluding zero. As soon as different orders of infinitesimals are considered, it will be seen that the infinities must be of the same order; and not only so, but by operating on the ratio f/g, so as to make it an infinity or zero of any required order, we can by similar or the converse treatment of θ, obtain infinities or zeros either of a still higher order, or on the other hand may maintain the intensity constant. *This would not be true if the lines were infinitesimally curved, i.e.* if p at ∞ were really p' at ∞, see Fig. 14.

18. *Space of non-uniform intensity.*—The idea of spatial variation of intensity, which has been illustrated in the preceding section, for a line, through linear projection, may be applied to

of the same order, or a surface whose radius of curvature is an infinity of higher order. The graphs of the two cases are pseudo-continuously represented in (*a*) and (*b*) respectively of Fig. 15, the ratio being represented on the y axes corresponding to any value of x.

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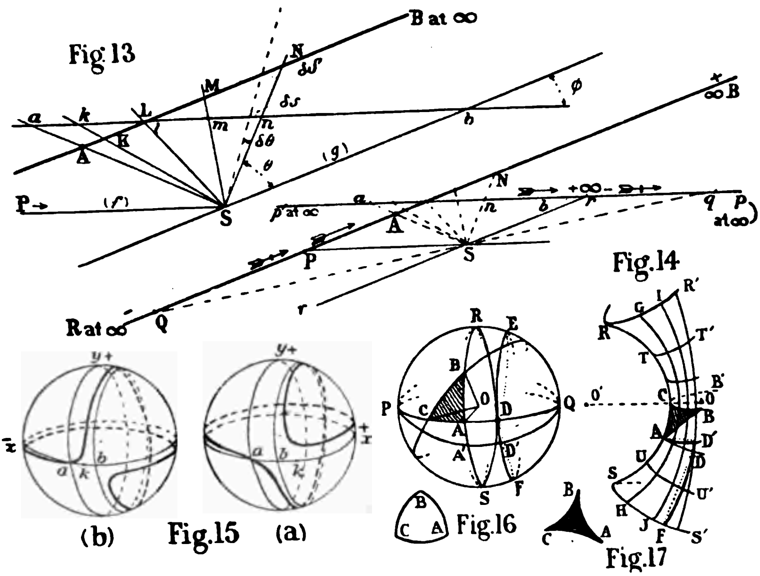

Fig. 13 Fig. 14 (b) Fig. 15 (a) Fig. 16 Fig. 17

hence for $\theta = 0°$ or $180°$, I is infinite; and when $\phi + \theta = 180°$ or $0°$, I is zero; the infinity and zero being of the same order. Again if f be zero, that is if S be infinitesimally close to the line RB, I becomes zero, for all finite values of ϕ and θ excluding zero; conversely if g be zero, f being finite, that is if S be infinitesimally close to the line ab, then I is infinite for all finite values of ϕ and θ excluding zero. As soon as different orders of infinitesimals are considered, it will be seen that the infinities must be of the same order; and not only so, but by operating on the ratio f/g, so as to make it an infinity or zero of any required order, we can by similar or the converse treatment of θ, obtain infinities or zeros either of a still higher order, or on the other hand may maintain the intensity constant. *This would not be true if the lines were infinitesimally curved, i.e.* if p at ∞ were really p' at ∞, see Fig. 14.

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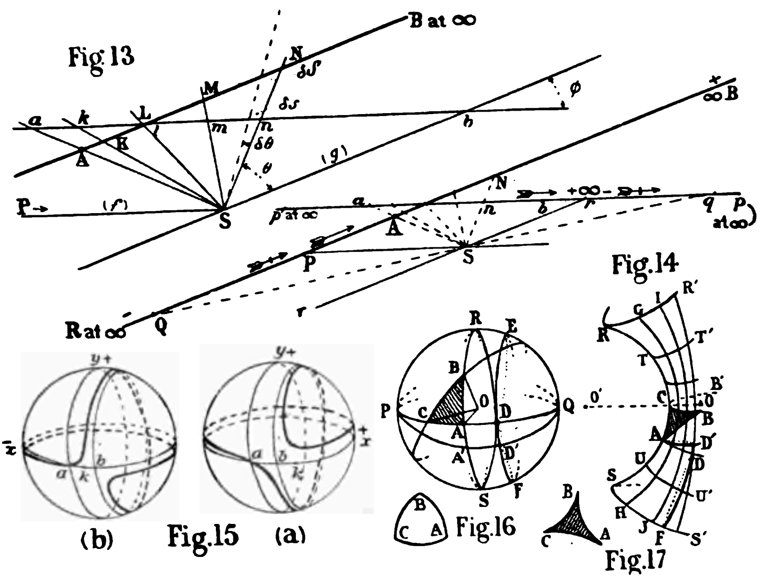

Fig. 13 Fig. 14 Fig. 15 Fig. 16 Fig. 17

hence for $\theta = 0°$ or $180°$, I is infinite; and when $\phi + \theta = 180°$ or $0°$, I is zero; the infinity and zero being of the same order. Again if f be zero, that is if S be infinitesimally close to the line RB, I becomes zero, for all finite values of ϕ and θ excluding zero; conversely if g be zero, f being finite, that is if S be infinitesimally close to the line ab, then I is infinite for all finite values of ϕ and θ excluding zero. As soon as different orders of infinitesimals are considered, it will be seen that the infinities must be of the same order; and not only so, but by operating on the ratio f/g, so as to make it an infinity or zero of any required order, we can by similar or the converse treatment of θ, obtain infinities or zeros either of a still higher order, or on the other hand may maintain the intensity constant. *This would not be true if the lines were infinitesimally curved, i.e.* if p at ∞ were really p' at ∞, see Fig. 14.

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nature of the theory may be explained as follows:—Let in Fig. 13, A, K, L, M, N, B at ∞ be any series of points on a natural scale, on one line, viz. the heavy one, projected from the point S on to another line—the projections being *a k l m n b*. Calling the heavy one the natural line, and the light one its projection, we observe that although the projection-lengths on the left are greater than the natural lengths, they become equal,[1] and then shorter, till finally the infinite distance NB is projected into the finite distance *nb*. In the opposite direction the finite distance AP, Fig. 14, is projected into an infinite line, $a-p$ at ∞. Assuming that equal stretches of the natural line, are in every way comparable, (*congruent*) and observing that the projective-ratio is continually changing, we reach the idea of a line of *non-uniform linear intensity*, so that if δS be a small element on the natural line, and δs its projection-equivalent, the intensity may be defined by the ratio $\delta S/\delta s$. Since the anharmonic ratio or its equivalent, or functions thereof are independent of the intensity, that ratio may be utilised to establish a theory of distance which will apply either to lines of uniform, or to lines of non-uniform intensity while ordinary conceptions of distance properly apply only to lines of uniform intensity.[2] Take any pair of points a, b, as *reference points*, then the anharmonic ratio of any other pairs together with these, viz. $(klab)$, $(lmab)$, $(kmab)$, may be written ρ_{kl}, ρ_{lm}, ρ_{km}, then we shall have[3]

[1] For the stretches LM, *lm*.

[2] The subjective idea of a traveller suffering ever-increasing fatigue, as to *equal* actual distances, takes the form of continual *increase* of linear value. A crank pin rotating uniformly about a centre, moves a piston-rod at one moment with its own velocity, in about a quarter of a revolution afterwards the rate of motion of the piston-rod has fallen to zero. The uniform recession of a pursued object may cause the pursuit to continually regrede till its actual rate is zero. Illustrations might be indefinitely multiplied as to the idea of intensity of related spatial elements.

[3] Measured by any units (*e.g.* the distance AK) the points k, l, m may be defined as κ, or λ, or μ, from a; and κ', or λ', or μ', from b (which may be denoted by the symbols $\kappa a + \kappa' b$, $\lambda a + \lambda' b$, $\mu a + \mu' b$); then the anharmonic ratios of the ranges, and the products of the ratios, are identically

$$\rho_{kl} \cdot \rho_{lm} = \frac{\kappa\lambda'}{\kappa'\lambda} \cdot \frac{\lambda\mu'}{\lambda'\mu} = \frac{\kappa\mu'}{\kappa'\mu} = \rho_{km}$$

and similarly for any number of ranges. Hence taking logarithms, we have (21) above. The points must be so taken as to give a positive ratio.

$$\log_c \rho_{kl} + \log_c \rho_{lm} = \log_c \rho_{km} \dots\dots\dots (21)$$

where the logarithm may be to any base c. Hence $\log_c \rho_{kl}$ may be defined as the *projective distance* between any two points k and l, and is determined by the place, not merely of the points themselves, but in relation to two reference points viz. a and b, which therefore may be called the *absolute point-pair*. Since the points AKL...B and $akl...b$ are *projective*, and therefore equianharmonic, the *projective distances of corresponding points are also identical*, although, as in the illustration, one of the points B is 'at infinity.' Reverting now to § 15 and to formula (18), it is easy to see that *this proposition is only infinitesimally approximate*[1] *for a first order infinity*, but is more nearly true for a higher infinity. If only one of the points k, l is between a and b the anharmonic ratio is negative, hence the distance as defined is impossible.[2] If the points be in the order $abkl$, and a be infinitely distant from b, then the anharmonic ratio becomes simply the ratio of the distances $bl : bk$ that is say l/k if l and k are reckoned from b. Hence if k become identical with b the anharmonic ratio is infinite unless at the same time a becomes identical with b, then it is 1. If l is at infinity the anharmonic ratio kl is the ratio of $ak : bk$, *i.e.* say κ/κ'.

Consider the finite range abk, and suppose x to move from $-\infty$ from a, across abk to $+\infty$ from a, then the distance ak being denoted by α and bk by β, the anharmonic ratio and distance D have the following values, x being always reckoned from a.

$x = -\infty^n$ to -0^n	$+0^n$ to $+(\alpha-\beta-0^n)$	$(\alpha-\beta+0^n$ to $\alpha+$ to ∞^n
$\rho_{xk} = \beta/\alpha$,, $+0^n$	-0^n ,, $-\infty^1$	$+\infty^n$,, 1 ,, β/α
$D = -y$,, $-\infty^m$	Impossible	$+\infty^m$,, 0 ,, $-y$

For the range akb however, $ak = \alpha$ and $bk = -\beta$ the results are:—

$x = -\infty^n$ to -0^n	$+0^n$ to α to $(\alpha+\beta-0^n)$	$(\alpha+\beta+0^n)$ to $+\infty^n$
$\rho_{xk} = -\beta/\alpha$,, -0^n	$+0^n$,, 1 ,, $+\infty^n$	$-\infty^n$,, $-\beta/\alpha$
$D =$ Impossible	$-\infty^m$,, 0 ,, $+\infty^m$	Impossible

These discontinuities are not representable except on an homaloid

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[2] Since it would be the logarithm of a negative number. There is a sense in which it may be called imaginary.

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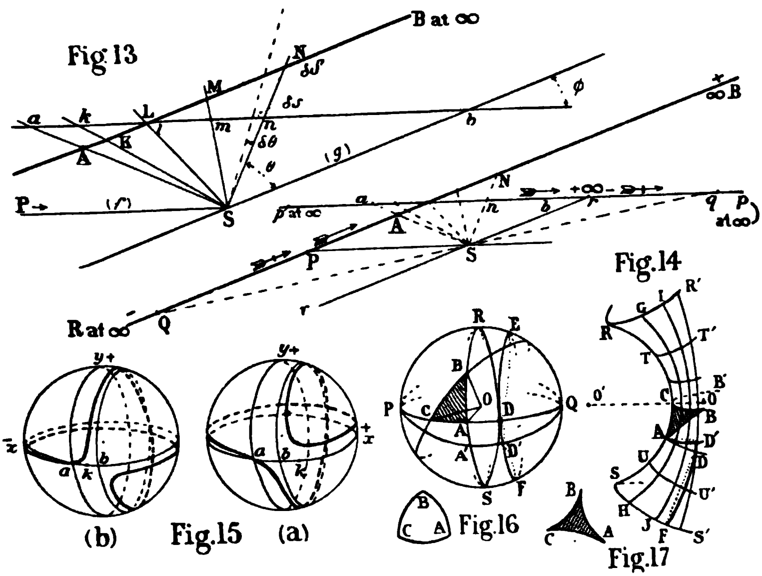

Fig. 13 Fig. 14 Fig. 15 Fig. 16 Fig. 17

hence for $\theta = 0°$ or $180°$, I is infinite; and when $\phi + \theta = 180°$ or $0°$, I is zero; the infinity and zero being of the same order. Again if f be zero, that is if S be infinitesimally close to the line RB, I becomes zero, for all finite values of ϕ and θ excluding zero; conversely if g be zero, f being finite, that is if S be infinitesimally close to the line ab, then I is infinite for all finite values of ϕ and θ excluding zero. As soon as different orders of infinitesimals are considered, it will be seen that the infinities must be of the same order; and not only so, but by operating on the ratio f/g, so as to make it an infinity or zero of any required order, we can by similar or the converse treatment of θ, obtain infinities or zeros either of a still higher order, or on the other hand may maintain the intensity constant. *This would not be true if the lines were infinitesimally curved,* i.e. if p at ∞ were really p' at ∞, see Fig. 14.

18. *Space of non-uniform intensity.*—The idea of spatial variation of intensity, which has been illustrated in the preceding section, for a line, through linear projection, may be applied to

space of any dimensions.[1] The variation in the case illustrated ranges between zero and infinity in a simple manner, which may be defined by the equation

$$I^{\frac{1}{4}} = k \sin(\phi + \theta) \operatorname{cosec} \theta \ldots\ldots\ldots (23a).$$

The projections of curves however will give lines of more complex variations of intensity. In the generation of geometrical figures, the generating elements may be assumed to follow any particular law of intensity in moving along, or in rotating about any axis, and consequently the generated space will not be homogeneous or isotropic,[2] though it may be homaloidal. Geometries of such space are possible; the intensities may preferably be supposed to vary with absolute continuity.

19. *Complex Space.*—Not only may space be assumed to be non-uniform in intensity, so that the spatial distribution of intensity shall follow any assigned law, but it may be supposed further to conform to different laws in respect of different properties. Such space may be called complex æolotropic space. Geometries which attempt to take simultaneous account of a series of laws of intensity will necessarily be extremely difficult.

20. *Space of positive and negative curvature.*—As already stated in supposed more general conceptions of "space" euclidean is proposed to be treated as a merely special or limiting case. "Space" in which two "straight" lines[3] can intersect only once, is known as *hyperbolic space*, and is infinite in some higher sense than

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[1] So far as I am aware, the formal recognition of intensity as applicable to any existing thing is due to Kant. See *op. cit.* "Anticipationen der Wahrnehmung." "Das Princip derselben ist: In allen Erscheinungen hat das Reale, was ein Gegenstand der Empfindung ist, intensive Grösse, d. i einen Grad. . . . So hat demnach jede Empfindung, mithin auch jede Realität in der Erscheinung, so klein sie auch sein mag, einen Grad, . . . die noch immer vermindert werden kann, und zwischen Realität und Negation ist ein kontinuirlicher Zusammenhang möglicher Realitäten . . . ." Elementarlehre, Buch II. Haupst 2, Abschn. 3 ii.

[2] Such conceptions are frequently realisable in physics, as for example an electric or magnetic field, variations in the density of bodies, non-uniform distributions of heat or other forms of energy, etc. These may all be regarded as space of non-uniform intensity, and a suitable geometry could be developed for each type of variation.

[3] Defined as the shortest lines between any two points, and supposed to be like the similar lines on three-dimensional surfaces.

euclidean space, which latter, being the lower limiting form of hyperbolic space is called *parabolic*, or homaloidal (*i.e.* "even" or "flat" space[1]). This also is infinite. Space in which two straight lines intersect twice, is defined as *elliptic space;* its upper limit being *parabolic*, *i.e.* infinite space, and its lower a point![2] Elliptic space has been divided into the *single-*, or the *polar* form, in which every line returns into itself (and two intersecting straight lines intersect really in the one point only, the second intersection being coincident with the original one); and the *double* or *antipodal* form, in which the second intersection is the antipodes of the first. Elliptic space is presumed to be *finite* in volume,[3] if its "constant" were not finite, it would be undistinguishable from parabolic space. Since a line cuts any plane only in one point, in the polar form of elliptic space, a single plane cannot divide it: two planes however can. In the antipodal form, since a straight line cuts it in two points, a plane does divide the space. Hyperbolic space is also divided by a plane. If any three points are taken in elliptic or hyperbolic space, and joined by "straight" lines, to form a triangle of area A, then its angles will be *greater* than 180° by the amount

$$\epsilon = \frac{A}{\rho^2} \quad \ldots\ldots\ldots(24)$$

that is *numerically greater* in elliptic space since ρ is then positive, and *numerically less* in hyperbolic space, since ρ is then negative,

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[1] Not surface.

[2] This latter limit to the conception is never insisted on: all that is urged (Clifford, Chrystal and many others) is that its volume is *finite* though *unbounded*, in the sense that the surface of a sphere is unbounded. It is left to the reader to satisfy himself whether a three-dimensional figure, *i.e.* a *volume*, can be unbounded and finite. The *scale* of the figure is of no moment: if the conception has validity it may be a microscopic quantum, an yet unbounded space. It is hardly necessary to add, that it is not a volume with an unbounded surface, but an unbounded volume.

[3] The greatest distance of two points is S, an absolute linear constant characterising the space: it is the distance one would have to travel on the straight line to return to the point of starting. In single elliptic space we should return inverted, as in passing along a tape rejoined after putting a 'half-twist' in it, and would have to traverse the distance $2S$ to become erect again! See Klein, Math. Annal. VI.; Chrystal, Proc. R. S. Edinb., x., 655. The volume of single elliptic space is

$$V = \pi^2 \rho^3 = S^3/\pi.$$

ρ being the radius of curvature.

ρ itself being a linear constant characteristic of the space, and analogous to the radius of curvature of a surface. This briefly indicates the chief properties of the two types of curved space.

21. *Geometrical illustration of elliptic and hyperbolic space.*— Suppose in Fig. 16, PRQS denote a sphere (*i.e.* a surface of constant positive curvature) whose centre is O. The shortest distances (geodesics) on its surface will be parts of great circles not greater than a semicircle; and are the *analogues*, on the surface, of straight lines on a plane.[1]

If the line EDD'F be equidistant from the great circle RAA'S,[2] it does not define the shortest distant between the several points: these would be parts of great circles indicated by the dotted lines from point to point, and would not form one and the same geodesic, *i.e.* the angles EDQ, QDD', etc., are less than right angles, if reckoned between the geodesics, and the line DQ etc., but are right angles only if reckoned from the equidistant line, Q being the pole of RAS. If R be the pole of PADQ, then the angles RAD, RDA, EDA are all right angles; hence there cannot be parallel or equidistant geodesics: that is, no figure on a surface of constant positive curvature can have its opposite sides equal and parallel and its four angles right angles. From the figure ADD'A, taking the dotted line DD', it is easy to see that the sum of the internal angles *exceeds* four right-angles, and that of the angles of the triangle ABO, *exceeds* two right angles. This excess is always

$$\epsilon = \frac{A}{\rho'\rho''} = \frac{A}{\rho^2} \quad \text{.........}(24a)$$

where A is the area of the figure and ρ' and ρ'' are the principal radii or curvature[3] at right angles to one another and ρ^2 is equal to their product, or in the sphere is the square of the radius.

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[1] A surface (the rectifying developable) can be drawn through any geodesic, in such a way that when it, the surface, is flattened into a plane (developed), the curve is a straight line.

[2] Like a parallel of latitude to the Equator on a map of the Earth.

[3] Or the product of the radii of curvature in any two directions at right angles to one another.

Fig. 17 denotes the saddle-shaped surface of (variable) negative curvature,[1] the centre of curvature of BCB′ being O and that of BCS, O′, CO and CO′ being opposed directions on the one line.[2] The system of meridians on the surface, cutting one another at right angles (like RAS, RDS, RQS, and PAQ, PA′Q, PSQ, Fig. 16) are RR′, TT′, CB, AD, UU′, SS′, and RCS, GH, IJ, etc. If AD′ is equidistant from CB, the shortest distance between those points is nearer to CB than the equidistant line, and similarly if D′F is equidistant from IJ, the geodesic is nearer AS: the fine dotted lines indicate their positions. A triangle ABC has the sum of its angles *less* than two right angles, or a quadrilateral BCAD′, less than four right angles, the amount of the defect being expressed by formula (24*a*).[3] As in the previous example parallel and equidistant geodesics cannot exist on a surface of constant negative curvature.

By analogy the two classes of surfaces suggest the possible existence of types of n-dimensional space, in which a system of 'straight' (!) lines[4] cutting another 'straight' line at right angles, should either *converge* and meet (elliptic space) or diverge and therefore never meet (hyperbolic space). It will be observed that the doctrine is obviously true for surfaces (not plane): *provided they are essentially three-dimensional;* but not otherwise. It may be *inferred*, therefore, that in a (supposititious) space of four dimensions, a three-dimensional space could be represented, which should have the properties indicated.[5]

22. *Symmetrical elliptic and hyperbolic space of two-dimensions.* —Since the sphere is a surface of uniform positive curvature, absolutely symmetrical in all respects, and unbounded, elliptical 2-dimensional space can be perfectly represented thereupon, and

[1] The *inner* side of a ring or tore, is a good example of such a surface.

[2] Thus the product of the radii is a negative quantity.

[3] That is, the excess is negative.

[4] These lines may start out from any point in all directions, maintaining relations of symmetry, from any point in 3-dimensional space.

[5] It will be seen the inference is of extremely doubtful validity, or rather that the space is not what we ordinarily conceive as "space."

Fig. 16 is therefore the required representation. The only type of surface upon which hyperbolic space of 2-dimensions can be delineated, is that indicated in Fig. 17. It is consequently evident from considerations of symmetry, that the completed or closed symmetrical surface, if such exist, must be a *tore* of some form,[1] Let RCS, Figs. 18, 19, be the axis of the ring: then the principal meridians of the surface will be as shewn by the heavy lines in Fig. 18, these are sections of the surface by planes containing the axis RCS. The equator of the surface would be the section perpendicular to that axis through MOM′, see both figures, and is shewn by the continuous heavy line inside the tore.

The short or incomplete equidistant lines are not geodesics, but parallels of latitude. The radii of curvature in the meridian and at right-angles thereto, at any point P, are respectively $PQ = \rho$, and $PR = \mu$; at a point like Q, they are respectively $QQ' = \sigma$, and $QS = \nu$; hence for a succession of points on these surfaces, we must have

$$\mu_1\rho_1 = \mu_2\rho_2 = \text{etc.} = \ldots = \nu_1\sigma_1 = \nu_2\sigma_2 = \text{etc.} \ldots\ldots\ldots (25)$$

if the curvature is to be *constant.*

In passing along the curves OK and KQ, μ and ν necessarily increase as K and Q are approached, each becoming finally infinite, hence ultimately ρ and σ will be infinitesimal. Consequently it is *not possible* to continue the curve starting at O beyond the points K and L as it must be continually convex towards the axis of the tore, and therefore concave outwards beyond the points K and L.

We can now see that it is not possible for the KM surface to be identical with OK unless CO is infinite; in other words *a finite and completely symmetrical hyperbolic surface does not exist.*[2]

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[1] See Figs. 1, 5, 18.

[2] So far as I am aware this has not been previously demonstrated. I give therefore the proof, which depends on the fact that KOL is a *cycloid,* if OC be infinite; KML being its evolute. The equation of the cycloid, O being the origin at its vertex, is

$$y = a \cos^{-1}\frac{a-x}{a} + \sqrt{(2ax - x^2)}$$

where a is the radius of the generating circle $Op = x$, $pP = y$. From this we deduce

23. *Impossibility of elliptic or hyperbolic space existing in a pure*[1] *homaloid of the same number of dimensions.*—We have seen that a symmetrical 2-dimensional elliptic closed space can exist in a homaloid of three dimensions, and that although a 2-dimensional hyperbolic space can be developed, it cannot possibly, if finite, be completely symmetrical, and in any case has singularities.[2] We proceed to shew that neither space can possibly exist in a homaloid of the same number of dimensions.

It is unnecessary to further discuss the impossibility in 2-dimensional space. Since 3-dimensional figures, in all three types of space, are identical when infinitesimal, the solid angle at every

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$$dy/dx = \tan\phi = \sqrt{\left(\frac{2a-x}{x}\right)};\ ds/dx = \sec\phi = \sqrt{\left(\frac{2a}{x}\right)};$$

hence putting b for the distance CO, we get

$$\rho = 2\sqrt{\{2a(2a-x)\}};\quad \sigma = 2\sqrt{(2ax)}$$

$$\mu = (b+x)\sqrt{\left(\frac{2a}{2a-x}\right)};\quad \nu = (b+4a-x)\sqrt{\left(\frac{2a}{x}\right)}$$

Hence

$$\mu\rho = (b+x)\,4a;\quad \nu\sigma = (b+4a-x)\,4a$$

Consequently if b be infinite, while a is finite, or if b be an infinity of the $(n+1)$th order while a is an infinity of the nth order only, the cycloidal curve and its evolute (and identical cycloid) satisfy the conditions that the radius of curvature $\sqrt{(\mu\rho)} = \sqrt{(\nu\sigma)}$ shall be constant throughout, and further that for equal distances from M toward K, and K toward O, the radii of curvature in and at right angles to the meridian shall be individually equal. In making $\mu\rho = \nu\sigma$; we must abandon the condition that the curve MQK shall be identical in shape with KPO if b be finite, for the parameters of the two curves necessarily differ, owing to the different distances from the axis of the tore; which establishes the proposition. It may be noticed that meridian lines diverge continuously in passing from the internal to the external equator. It is worthy of remark that there is a very characteristic difference between the surface developed by rotating KOL about RCS and an hyperboloid of one sheet; that is the cycloidal surface *cannot*, and the hyperboloidal *can* be generated by the motion of a straight line. Again for the same curvature at O, the centre of curvature moves from M *towards* the curve in the case of the cycloid and *away* from the curve in the case of the hyperboloid. A straight line cannot of course lie on a surface of constant positive or negative curvature. It may be added that a solid of constant negative curvature would be of the form shewn in Fig. 18*a*, the curves not differing greatly from cycloids: the curves are obviously not identical.

[1] That is an homogeneous and isotropic homaloid.

[2] One may say that O is the position at the equator of the surface LOK, and K and L, of the surfaces KML in other respects the latitude characteristics are inverted. The singularities at KL and M, show that the surface cannot be continuous in the proper sense of the term.

point, O Fig. 20, throughout each kind of space is always 4π measured in steradians.[1] Consider a plane drawn through this point and imagine a series of lines running out from it, to be traced on the plane, so as to include angles of any given size, $\frac{1}{3}\pi$ in figure. In elliptic space these must be curved toward one another as AOA′, B′OB′, on the left side of figure, since otherwise the three angles of every triangle will *not* total $\pi+\epsilon$, hence the line OA′ must be identical with OB′ and the voids A′OB′, B′OC′ do not exist. Let OA and OA′ be continued to O′, OB′ to O″, and OC′ to O‴. These three if the curvature be constant will be the one point, which, being impossible, proves that the curvature cannot be regarded as existing in the initial plane. This however is true of every other arbitrary plane in the homaloid of 3 dimensions: hence the conception of *lateral* curvature is an impossible one.

Neither can it be assumed to act say *perpendicularly* to the initial plane, for supposing the angles at O Fig. 21 to be the same as those at O Fig. 20, the curvature must, for the space to be homaloidal, be indifferently in the direction OO′ and OO″ *at the same time:* hence the curvature perpendicular to the plane angle is equally impossible.

Similarly if the angles from O, Fig. 20, are angles of triangles the sums of whose interior angles are $\pi-\epsilon$, the 'straight' lines OA, OB etc., must be curved outwards: but AOA, cannot overlap BOB as shewn by double shading; that is OB is the same line as OA. As this must be equally true in all directions, negative curvature cannot exist either laterally, or in any other direction: *i.e.* the conception of curved 3-dimensional space is absolutely incapable of geometrical representation in a homaloid of three dimensions. We infer therefore, that in an isotropic and homogeneous homaloid of n-dimensions the theory of curvature for space of n-dimensions is *invalid.*

[1] A unit steradian is the solid angle subtended at the centre of a sphere by a surface equal in area to the square on the radius. The surface divided by this unit is $4\pi r^2/r^2 = 4\pi$.

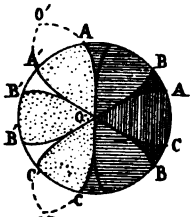

Fig. 20

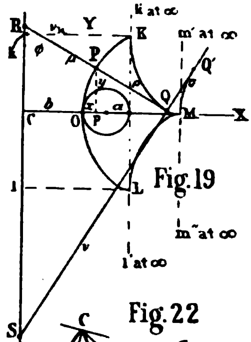

Fig. 19

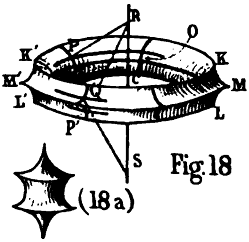

Fig. 18

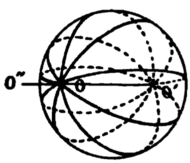

Fig. 21

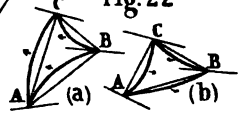

Fig. 22

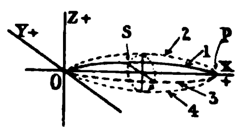

Fig. 23

24. *Is elliptic and hyperbolic space of* n *dimensions representable in space of* (n + 1) *dimensions?*—Consider the circumference of a circle, and the surface of a sphere: these are geometrical figures without terms. As line and surface they are respectively 1- and 2-dimensional figures, but as boundaries they are respectively 2- and 3-dimensional; and we have seen that if the radius of the circle or sphere be infinite, they are pseudo- or finitely homaloidal, see § 12. Observing further that the boundary of a surface is a line, and that of a solid is a surface, and remembering that a 4-dimensional quantum is (conceptually) generated by the motion of a solid into the fourth dimension, see § 4, we conclude that *space of* n *dimensions, is, conceptually, the boundary of space of* $(n+1)$ *dimensions.* Consistently with the developments of §§ 7, 9, and 12, we may define an n-dimensional homaloid as the boundary of an $(n+1)$ dimensional space, whose $(n+1)$th axis only, is infinitesimally curved, positively or negatively: consequently the question arises whether the n-dimensional space will be elliptic or hyperbolic according as the curvature, if finite, is positive or negative, as represented in Fig. 22. *In* the tridimensional or ordinary homaloid the triangles A B C are, by hypothesis, plane—the curvature not existing on their tridimensional repre-

sentation—consequently the lines, if really bent,—as indicated by arrows—are not bent in the third dimension of space, but *if at all* in some other dimensions.[1] These others, being conceptually perpendicular to each of the other three, have, *it might be supposed*, the effect of altering the plane angle from what it would have been, had the lines been *uniquely* straight. If such a view be correct, uniquely straight lines must be straight with respect to all *possible* dimensions, because the effect, *if any*, will be the same if the curvature be in any one of the supposititious n dimensions including the first three.

Curved space, to affect the angles of a triangle must, however, obviously be curved in all dimensions, since its radius of curvature will be

$$\rho_0 = (\rho_1\rho_2 \cdots \rho_n)^{\frac{1}{n}} \ldots\ldots\ldots\ldots (26)$$

and if any quantity is infinite, ρ_0 is infinite, unless some other quantity is zero, a case the consideration of which can be set aside as unnecessary.[2] Consequently even though n-dimensional space is only the boundary of a space of $(n+1)$ dimensions, *if any dimension is without curvature*, angles between geodesics in that space are not affected and will total $\pi\ (n \pm 2)$. Hence the tests proposed to be applied by Lobatchewsky, Helmholtz, and others, would fail, if space is not curved in each dimension of space.

The invalid nature of the supposition that "actual" space may possibly be curved, may be further realised as follows:—With O as origin, let the values of the coordinates of the terminal P of a line OSP, Fig. 23, be x, 0, 0; S being the middle point. If the line be curved in *any direction*, in the plane xy let us suppose, that is if it be bent in the direction $+y$ only, it will on rotating be bent successively in the directions $+z$, $-y$, $-z$, that is to say the existence of the curvature will be revealed in other directions

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[1] That is to say, Fig. 22 cannot be a picture of the lines, since the difference between the curves and the lines AB, BC etc., are in the supposititious dimensions.

[2] In the cylinder and cone the surface is straight in one direction curved at right angles thereto. Hence $\rho_0 = \sqrt{(\rho_1 \infty)} = \infty$: consequently the angles are not affected.

in space, than that in which it originally existed. Similarly if the coordinates of P be x, 0, 0, 0 and of S, $\frac{1}{2}x$, $y=0$, $z=0$, $w=h$, w being at right angles to each of the other dimensions, rotation will cause the curvature to appear in the xy and xz planes, (See § 11), so that h can be measured, although (supposititiously) it was unrevealed while in the fourth dimension.

If it be objected that the curvature appears because the plane, vertical to the line x, is the yz plane, it may be remarked that w is in every sense as much at right angles to the xy plane, as to the xz, and if, on rotating, the position of the line does not vary, whatever curvature in the w axis may mean, it is something which cannot, as evidenced by that test, affect the angles of inclination in tridimensional space: which is equivalent to affirming that the supposititious curvature has no existence.

It is now obvious that tridimensional elliptic and hyperbolic space cannot "actually" exist, if a line joining any two points can be rotated in a plane perpendicular thereto without varying its position in a surface perpendicular to the line. This is essentially identical with the following proposition:—*A line is uniquely or absolutely straight,*[1] *if, when orthogonally projected in tridimensional space on any two planes perpendicular to one another, its projection in both is a straight line.*

Mathematicians who allege that our space may be "curved space," do not imply that it is "visibly curved" in any plane, but that the curvature would appear in the "excess" or "defect" of the three angles of a triangle, with respect to the homaloidal value π, a fact inexplicable in homaloidal space, and demanding for its interpretation the assumption of a curvature in what *to us* is an imaginary dimension of space. If *visibly curved*, the line is neither a straight line, nor the shortest distance between the points.[2] We may conclude therefore that *geometrically, elliptic*

[1] Straight in every *spatial* dimension.

[2] It is perhaps necessary to say that it is not pretended that lines are merely *refracted*, we refer to this later.

and hyperbolic space have no existence, as representing a possibility of "actual" space.[1]

25. *Elliptic and hyperbolic space merely a specialised region in a homaloid.*—The confidence which mathematicians have felt as to the possible existence of types of space other than homaloidal, has arisen from the inherent consistency of "analytic or symbolic geometry." In the introduction to this paper, it was pointed out that a region of space may be specialised, as for example, by being referred to curvilinear axes, varied in intensity, regarded as æolotropic, or supposed to be otherwise specially constituted. Any specialisation of space whatever that can be represented by symbols, has its appropriate analytical geometry, or scheme of symbolic operation, in which geometrical interpretation is indifferent until necessitated in applying the final results. The belief that algebras, as such, can establish results which reveal the true nature of "actual" tridimensional space, or reach results that, though fundamentally affecting the concepts or intuitions of space, cannot immediately be apprehended by pure geometry, is based upon a complete misconception of the nature of the "actuality" of space. The function of geometries, either analytic, metric, or projective, is to reveal the properties, not of space, but of geometrical figures either in pure space, or in any specialised space which can be clearly conceived, and interpreted into and from the symbols.

In pure space, any geometrical figure whatever, (*e.g.* point, straight or curved line, plane or curved surface, or solid of any form) may exist, because conceptually they are spatial, while space of $(3+m)$ dimensions is purely abstract in regard to every one of the m dimensions, and is spatially not representable, though by analogies, such space is schematically representable. Elliptic and hyperbolic geometries refer therefore to figures in space or to space specially constituted, as for example, space filled with a refracting

[1] Stringham affirms "there is yet no theory of knowledge that can tell us which of these three diverging paths we must take" *i.e.* interpret space in terms of parabolic, elliptic or hyperbolic geometry, vide "On the fundamental differential equations of Geometry"! Journal B. A. A. Sc. 1899, p. 647. With this dictum we of course, join issue.

medium, in which if the length of lines be measured by the time necessary for an æthereal disturbance to pass from one point to another, the shortest line is curved and not straight. For such a medium a straight line, spatially the longer, is in a temporal sense the shorter.

26. *Space of* n-*dimensions as the boundary of* $(n+1)$ *dimensional space.*—In the generative scheme of § 4, space of n dimensions is to space of $(n+1)$ dimensions the analogue of a boundary, as pointed out in § 24. The idea of space of one type being a locus in space of another of higher dimensions, was conceived by Johann Bolyai, and by Beltrami. It is shewn by Whitehead,[1] analytically, that "euclidean space of n dimensions can be conceived as a limit-surface of hyperbolic space of $(n+1)$ dimensions," and he remarks: "There is an *error*,[2] popular even among mathematicians misled by a useful technical phraseology, *that euclidean space is in a special sense flat*,[3] and that this flatness is exemplified by the possibility of a euclidean space containing surfaces with the properties of hyperbolic and elliptic spaces. But the text shews that the relation to hyperbolic to euclidean space can be inverted. Thus no theory of the flatness of euclidean space can be founded on it." This dictum is based upon a theory of the relations between the sides and angles of a "*curvilinear*" triangle formed by great circles on a "limit-surface."[4] Now it may be remarked that "curvilinear" must be defined for such a statement to be intelligible. Reverting to the illustration of refraction in last section, the "shorter" line, *i.e.* the curved one, may be regarded as straight in the geometry which measures its unit of length, and the actually shorter line—the really straight one, may be regarded as curved. And generally any line, curved or tortuous, may geometrically be treated as straight and be made the basis of a geometry of the form of any other lines, straight or curved. More generally, a geometrical figure of n dimensions may be treated as a "*flat*" for the develop-

[1] Universal Algebra I., p. 451.
[2] The italics are mine. [3] The word is Whitehead's.
[4] For the theory of limit-surfaces see Whitehead *op. cit.*, I.; pp. 447-8.

ment of a theory of a figure of $(n+1)$ dimensions. This treatment is what may be called relative, as distinguished from absolute; and in applying any deductions of analytic geometry the essential features of the relation must be borne in mind, the deductions being applicable only where analogous relationships exist. The fundamental conceptions of geometry are however an *absolute* basis, in the sense that any discredit thrown upon them, reduces *all* geometry to confusion. The relativity of figure we now proceed to consider.

27. *Relativity of geometrical forms and figures.*—In the introduction, reference was made in a footnote 1, page 249, to the relativity and reciprocal identity of solar and cometary motion in space, the two curves of apparent motion being the same conic sections, that is to say either the sun or the comet could be regarded as moving in the conic, the direction and amount being identical, but the coordinates differing 180°. This is a very elementary case of relativity. We proceed to indicate a more complex case. In the line (or surface) Q_2O' Fig. 24, suppose successive points to be determined by their distances Q_2P_2 from the line (or surface) P_2O, measured vertically to the latter, and the distances OP_2 on the reference line. Then treating this latter as a straight line, the successive points 1, 2, 3, etc., on the absolutely straight line OS become relatively thereto the curve $Q_2O'S$ Fig. 25, and relatively to this curve the circular arc is a straight line.[1]

That is to say, given only x and y, and that y is always perpendicular to x, but no knowledge of the curvature of x, the absolutely straight line would appear as the curve in Fig. 25, and similarly coplanar points, as distributed over a conoidal surface, of which Fig. 25 is the section. In one sense it is indifferent whether OP is regarded as straight and OQ as curved or *vice versa*, but not

[1] The equation to the curve is obviously

$$y = \sec\frac{x}{\rho}(\rho+b)-\rho$$

y being the vertical PQ, x the curved line OP, b the distance OO′, and ρ the radius of the circle. The curve in Fig. 25 has asymptotes at $\pm\frac{1}{2}\pi\rho$.

absolutely so. The intensity of the lines OP, OQ Fig. 24 being uniform, and OX in Fig. 25, the intensity of the curve QO'S in the latter figure is not uniform, that is to say its linear value does not coincide with that of corresponding points in QO'S Fig. 24.[1] Hence the integral of the curve O'S, for its length as in Fig. 25, is

$$s = \int \surd \left\{ 1 + (dy/dx)^2 \right\} dx \ldots\ldots\ldots (27)$$

while the real length of the line as in Fig. 24 is:—

$$S = \int I \surd \left\{ 1 + (dy/dx)^2 \right\} dx \ldots\ldots\ldots (27a)$$

I being of course a function of x, as indicated in the preceding footnote.[2] It is evident therefore that *a complete theory of relativity must include relativity of intensity as well as mere relativity of position*, (See also § §, 16, 17, 18), and specialisations of space are not inversely comparable unless both intensity and position are taken into account. This however implies that the results are general only when the space is a definite specialisation of an isotropic, homogeneous homaloid. The cases cited, illustrative of a relativity of position and intensity, indicate that its complexity has no limit.

28 *Complex generation of geometrical figures of uniform intensity.*—In the preceding sections, treating of the generation by summational, fluxional, or rotational operations,[3] no account was taken of more complex processes. If the elements from which a circle of radius r is built up (summationally) be of intensity α in one direction, and β at right angles thereto, its intensity-area is $\pi\alpha\beta r^2$; that is it is equivalent to the ellipse with semi-axes αr, βr; and if it be supposed to have been compressed and to expand till the intensity was uniform, it would be actually an ellipse with those axes.

---

[1] Let δS denote the length of any small element of the line O'S, and δs the length of the corresponding element in the curve O'S (Fig. 25). Then the intensity I, see (23) § 17, is

$$I = \delta S/\delta s = \mu / \surd(\cos^4 x/\rho + \mu \sin^2 x/\rho)$$

μ denoting $1 + b/\rho$.

[2] The lengths corresponding to points 1, 2, 3 etc., on the line O'S Fig. 24, are marked by the points i., ii., iii. etc., on Fig. 25. The distance from the corresponding 'arabic' numerals shews the difference.

[3] §§ 2 – 6, and 11.

Similarly a sphere built up of elements differing in intensity in three directions, but constant in each direction will be as to its intensity quantum, an ellipsoid, the intensity volume of which is $\frac{4}{3}\pi\alpha\beta\gamma r^3$, if the axes be perpendicular to each other.[1]

If a line r be rotated about one end, the path of its *term* is of course the circumference of the circle, formed by the path of the line itself; if in rotating, the radius be increased or diminished proportionally to the arc through which it is turned, the term traces out the spiral of Archimedes,[2] while if in rotating, it lengthens or diminishes as expressed by the equation $r = a^\theta$, the path of the term is an equiangular or logarithmic spiral.[3] This generation is continuous.

In Fig. 26, suppose a line r, viz. RS, perpendicular to the axis ZO, to increase its length, according to the law implied by the equation $r = \sqrt{(az - z^2)}$, z being the distance ZR; its term S will be a spiral on a spherical surface, if it revolve with infinite velocity while it moves along ZO with finite velocity, it may be considered to trace out the spherical surface itself.[4] The surface generated by the line RS will be the helical surface represented near Z in the figure. A more complex surface will be generated, if RS be a curve, changing its parameter as it moves along z, or changing according to some more complex function of z; and if the z axis be curved, the complexity will be still further increased.

Thus by the most simple operations very complex geometrical figures[5] may be generated. On the other hand apparently complex motions may develope simple figures. For example the terms

[1] Many formulæ become obvious from this point of view, *e.g.* volume of an ellipsoid is $= \frac{4}{3}\pi abc$.

[2] $r = a\theta$.

[3] This may be traced by attaching a thread to a point on the surface of a right circular cone, whose axis is perpendicular to the plane on which the vertex of the cone lies. Draw the thread tight and wind it round the cone: if it does not slip the terminal P of the thread, kept on the plane, will trace the curve.

[4] More strictly a spiral line, whose winding on the sphere is only separated by an infinitesimal distance, a being *finite*. In respect to the spherical surface this generation is not continuous.

[5] Or figures that may be regarded as representing them.

(O′P′Q′) of the reciprocals the (OO′, OP′, OQ′) of the coinitial vectors (OZ, OP, OQ), whose extremities ZPQ lie in a spherical surface, are coplanar. That is to say, if the term P of a vector OP move over the entire surface[1] of the sphere OQZ, the term P′ of its reciprocal will trace out an infinite circular plane.[2] Or again, if a point P starting at the pole Z, move on the sphere so that its polar distance ($ZP = \phi$) bears a constant ratio to its longitude (ω say, *e.g.* $\phi = 2m\omega$) the reciprocal of its distance to the opposite pole PO, will trace out the curve $r = b \tan m\omega$ lying wholly in a plane.[3] It is obvious that there is no limit to the complexity of possible forms capable of geometrical development, and on the other hand simple figures may be generated from the most complex. Forms of generation in which a line is developed from a pure point in any other way than by motion along it, or a surface from a line

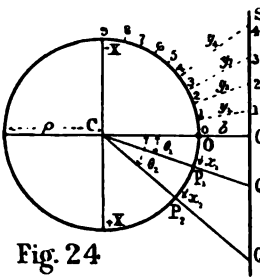

Fig. 24

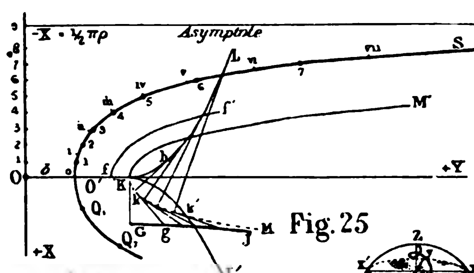

Fig. 25

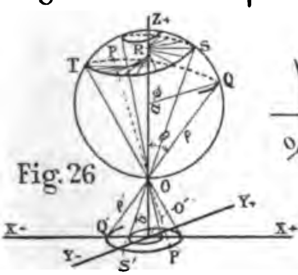

Fig. 26

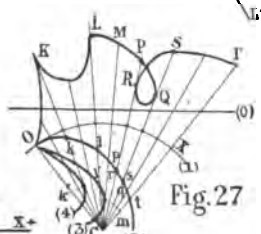

Fig. 27

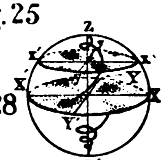

Fig. 28

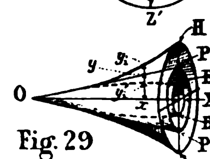

Fig. 29

[1] This is really an impossible supposition, since the term is a pure point, and no scheme of motion can make it cover a surface.

[2] Obvious, since $OQ \,.\, OQ' = \rho\rho' = a \cos\theta \,.\, b \sec\theta = ab$.

[3] r becomes infinite only when P reaches O, *i e.* when $m\omega = \frac{1}{2}\pi$. It may be noted that the infinity depends on the order of the infinitesimal approach to O by the point P.

except by motion across the surface, or a solid from a surface except by motion in it, are essentially impossible, but the generated figure may be understood as representing the continuum as a row of points may be regarded as representing a line.

29. *Involutional, evolutional, pedal, modular and umbilical generation.*—The terminal K of a string, unwound from the curve KhL, Fig. 25, would trace out the dotted line Kkk'M, the *involute* of the curve; in a similar way KM', the involute of KL' could be defined. In the latter case if the length of the string were Kf, or KO, instead of being originally zero, the involute would be ff' or O'S.[1] Suppose the line hk, which is obviously equal to the hK, to vary in any definite way, *i.e.* as some continuous function of the angle through which it turns, the point K (or f, O', or O) may be said to generate a curve *involutionally:* such a scheme of generation would obviously be continuous.

On the other hand imagine a point, to which a string OKY is attached, to move along the curve O'S, and to be kept perpendicular to the tangent to the curve of the moving point; the successive positions of the string would *envelope* the curve KL', called its *evolute.*[2] If the distance along the straight line which envelopes the evolute, is any continuous function of its total length, measured from curve to evolute, or if the length be any continuous function of the angle through which the string turns, the curve traced by the terminal may be said to be *evolutionally* generated. This also is a continuous scheme of generation.

Again let a line KG, Fig. 25, make some definite angle with the radius of curvature[3]—it need not necessarily touch the curve Kk'M—and let the point K be moved with the radius: or what is the same thing let a string unwind from the curve KhL and the line KG make a definite angle with the string kh: the curve

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[1] The lines are equidistant measured along the string and are therefore generally described as *parallel.*

[2] Observe the lines kh, k'L, enveloping the curve KkL. The distance from the point to the evolute perpendicularly to the tangent is the *radius of curvature* of the *osculating circle.*

[3] See footnote 1, above.

traced by the terminal G is a *pedal* curve. If the line hk be a continuous function of its own distance or of the angle through which it turns, and the line KG, or kg, make an angle therewith, which is either constant, or a continuous function of the distance kg, or of the angle through which that line turns, the curve traced by the point G may be said to be *pedally* generated.[1] These three generative schemes are substantially identical in principle, and may be all characterised as pedal generation.[2]

Three-dimensional figures may similarly be generated, either from three-dimensional surfaces, or by the rotation of two-dimensional figures. In generating by rotation the radius of curvature may also be a function of the angle through which it turns. A surface of revolution would be continuous, but for the generated surface to be continuous in other cases it must necessarily be defined by the involutional, evolutional or pedal surface, defined as the locus of the generating points, the centres of curvature, or the pedal points.

We pass now to examples of more purely functional schemes of generation, *e.g.* modular and umbilical generation.

When the locus of points is determined by the *constant* ratio[3] which their distance from some fixed point[4] bears to their distance —measured parallel to a fixed plane[5]—from some fixed straight line,[6] the surface in which the points lie, or which is thus represented, is said to be *modularly* generated.[7] The ratio, or modulus, may be continuously varied in any specified way, that is it may be

[1] GgJ is a simple type of pedal curve.

[2] Evolutes and involutes were discussed by Huygens as far back as 1672 in his Horologium Oscillatorium, by Tschirnhausen (Acta Eruditorum 1682) by Leibniz, *ibid.*, 1686, and by Newton (Principia).

[3] The modulus. [4] The modular focus. [5] The directing plane. [6] The directrix.

[7] The ratio being constant the locus may be an elliptic paraboloid, an elliptic or parabolic cylinder, a hyperbolic paraboloid or cylinder, an ellipsoid, or hyperboloid of one or two sheets, the oblate spheroid and hyperboloid af revolution of one sheet. The prolate spheroid, and hyperboloid of revolution of two sheets *cannot* be modularly generated. The subject has been treated by MacCullagh, Salmon, Townsend, Frost and Wolstenholme, and others.

a function of the direction of any point from the fixed point or modular focus, this may be called *complex modular generation.* Modularly generated surfaces are of the second degree if the ratio be *constant.* When the square of the distance from the focal point[1] to the point on the surface bears a constant ratio[2] to the rectangle whose sides are the perpendiculars to two fixed planes,[3] the surface is said to be *umbilically* generated, and is a surface of the second degree, or a *conicoid.*[4]

As in modular, so in umbilical generation, the modulus may be continuously varied, in which case it may be called *complex modular generation.*

It is obvious that by variations of the moduli, any system of points generated may lie on a surface of any degree of complexity. These methods of generating geometrical figures give point-systems, rather than continuous surfaces.

30. *Generation of figures of non-uniform intensity.*—Figs. 13, 14, and 25 afford examples of lines of non-uniform intensity, the law of variation of the intensity being simple in each case. In generating any geometrical figure, the generatrix, conceived as imparting its own characteristics to the space through which it passes, may itself be of non-uniform intensity; its intensity may vary during the generative motion in any specified way; a geometrical figure may be obtained not directly from the generative scheme, but from the projection of the generated figure; or, it may be, from any combination of projections. In these and many other ways, the heterogeneity and æolotropy[5] of geometrical

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[1] The umbilical, instead of modular, focus. [2] The umbilical modulus.

[3] The planes are called directing planes, and their intersection the directrix.

[4] The surfaces that can be generated (with real focus and directrix) are the ellipsoid, hyperboloid of two sheets, elliptic paraboloid, a cone point. The hyperboloid of revolution of two sheets and the prolate spheroid *can* be umbilically generated.

[5] It is generally convenient to restrict the antithetical words "homogeneous" and "heterogeneous" to the implication of mere differences of density; and "isotropic" and "æolotropic" to differences in the properties of a body, which may nevertheless be of uniform density. As the idea of intensity is not by any means synonymous with density, æolotropic will perhaps convey the more general meaning.

figures may be involved. In Fig. 27 the effect of projection on intensity is more fully illustrated. Suppose OKL...T to be a curve of uniform intensity radially projected from the point C on to the curves 0, 1...4. The simplest relationship will be on the straight line (0); on the circular curve (1) the relation will be more complex; and, on the curve of changing curvature, viz. (2) still more so. Although at the points k, l, l′, r, q in (2) the intensity is infinite,[1] it is finite for all finite distances however small. At a point like m it is zero, but at one like k′, where the line CK is tangential to both curves, it depends upon the ratio of the differentials of the curves, CK being adopted as axis. The mean intensity of the stretch ps is the total length PQRS divided by ps; and similarly throughout. A moving point, in generating any line, may be assumed to vary its intensity in any given way: so also in regard to a line generating a surface, a surface generating a solid, a solid generating a fourth dimensional quantum and so on. The possible schemes of varying intensity are obviously illimitable, consequently the complexity of specialised regions of space may be varied in an infinite number of ways. It is evident from this point of view that the so-called elliptic space, and hyperbolic space are simply some of the most simple forms of specialised regions of space.[2]

In generating an æolotropic or heterogeneous spatial region, say of spherical (or ellipsoidal) form, its heterogeneity or æolotropy may vary periodically on non-periodically along the radii, or in the parallel planes dividing it into circular (or elliptic) sections; and the variation of the intensity on the radius in the *xy* plane, may be periodic as it rotates in that plane. Thus, as this plane moves along the *z* axis, the points of maxima and minima may be rotated, and the period so varied, that if the æolotropic variation be continuous, the lines of maximum intensity, would form a spiral of varying intensity. Fig. 28 will afford an illustration, the

[1] The radial lines being tangential to the curve at K, L, R and Q.

[2] A magnetic or electric field may be instanced as an elementary example of specialised space.

a function of the direction of ... XY, XY denoting the modular focus, this ma... focus of one of its maxima.[1] Modularly generated ... with a suitable distribution of be *constant*. Whe... path, for motion affected by the point[1] to the po... regarded as the *straight* lines of the space; rectangle who... is in general tortuous space.

the surface ... intensity-volume of æolotropic space.—Æolotropic the secon... with respect to volume only, is of course, not

As i... measured from ordinary space; if however its intensity is cont... differentiated, that is if an element thereof be m... taken into account,

$$\delta V_1 = I_{xyzw\ldots}\, \delta x\, \delta y\, \delta z\, \delta w \ldots \quad \ldots\ldots\ldots(28)$$

in which V_1 denotes the *intensity-volume* $I_m V$, or the mean intensity multiplied by the spatial volume—this is no longer true. It must suffice to take a single illustration of an elementary character. Suppose that the linear intensity in a spherical space surrounding the point O, is some such simple function of the distance r therefrom, as

$$I_1 = 1 + ar^n \quad \ldots\ldots\ldots(29)$$

where a is any finite number,[2] and n is positive or negative. The intensity-volume is obviously

$$V_1 = 4\pi \int (1 + ar^n) r^2 dr = \tfrac{4}{3}\pi r^3 + 4\pi a \int r^{2+n}\, dr \quad \ldots\ldots\ldots(30)$$

that is to say when n is -3

$$V_1 = \tfrac{4}{3}\pi r^3 \left(1 + 3a \frac{\log r}{r^3}\right) \ldots\ldots\ldots(31)$$

and in all other cases

$$V_1 = \tfrac{4}{3}\pi r^3 \left(1 + 3a \frac{r^n}{3+n}\right) \ldots\ldots\ldots(31a)$$

[1] The distribution of an electrified powder on an electrified resinous cake, in Lichtenberg's experiments—Chladni's sand-figures on a vibrating plate, on Strehlke's or Faraday's modification of this experiment, the distribution of liquid spherules in a vibrating bell partially filled with liquid in Melde's experiment—may be taken as illustrating the actual distribution of intensity.

[2] In the atmosphere a ray of light is bent toward the normal to the surface, when the pressure and temperature vary uniformly upwards. Measured by a time-unit this curve is the shortest path, owing to the irregular distributions of temperature and pressure the actual path of a star's light is always more or less tortuous.

[3] Which we shall see may be positive or negative. For simplicity's sake we may suppose the intensity at O to be unity if n is positive. If negative it will be infinity.

The part to be *added* to the volume to correct it for intensity is therefore for $n = -3$, and generally

$$V_1 - V = 4\pi a \log r, \text{ and } 4\pi a \frac{r^{3+n}}{3+n} \quad \ldots\ldots\ldots(32)$$

respectively. The values of this are[1]

Values of

$n =$	$-\infty$	-5	-4	-3	-2	-1	0	$+\infty$
$V_1 - V = 4\pi a \times$	0^p;	$-\frac{1}{2r^2}$;	$-\frac{1}{r}$;	$+\log r$;	$+r$;	$\frac{1}{2}r^2$;	$\frac{1}{3}r^3$;	∞^q

When n is between -4 and $-\infty$, the intensity at the point O is infinite: on the other hand it may be made zero at any distance from O that we please, by taking a negative and suitably choosing a and n. Beyond this distance the intensity will be negative. *Negative intensity* may be defined as *any affection of a spatial unit, such that if it be combined with an equal but opposite affection of an equal unit, the result will be null.*[2] Zero-intensity implies the non-existence of the affection.

32. *Conversion of æolotropic into isotropic space.*—Let OX, Fig. 29, denote the axis of a cone POP′ in an æolotropic homaloid of three dimensions: and first let it be supposed that the density in a line, x to y, perpendicular to the axis, is uniform but increases as x, the distance from O, increases. Suppose the cone to expand parallel to XP only, till the density was uniform, the form would be similar to HOH′. What were originally straight lines would be bent outwards and we should have all the characteristics of *hyperbolic*, developed from *parabolic* space.[3] Conversely, suppose the density to diminish as we move along OX, and the cone to be similarly compressed till of uniform density, we should have as

---

[1] If $n=0$ and $a=1$, which, see (29), means that we assume the intensity to be zero throughout, the result for the intensity-volume, is of course zero also.

[2] Let V denote the potential at a point P of a sphere of density 2δ in a region of space of density δ. (*i.e.* the sphere has an excess of density δ over that of the space in which it lies) and let V' be the potential of the void space, when the sphere is removed (*i.e.* when the defect of density is δ). Then $V' = -V$, V and V' may be regarded as equal and opposite intensities, *i.e.* as $+I$ and $-I$: so also *in this case* $+\delta$ and $-\delta$ may be regarded as equal and opposite the affections of space.

[3] See the right hand side of Fig. 20.

the result the conoidal form EOE′, what were straight lines originally being now curved inwards, and the characteristic features of *elliptic* space would have been developed.[1] Tortuous æolotropic space may be reduced to isotropy by expansions, contractions, and rotations, linear motion being included in the last.

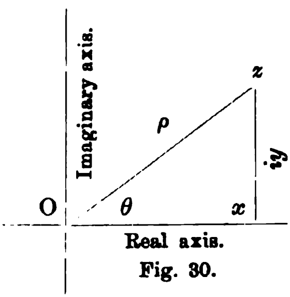
33. *Conformal representation of functional dependence.*—The part played in the modern theory of functions by the numerically impossible quantity $\sqrt{-1}$, called therefore *imaginary*, is of such moment, that a consideration of the principle of continuity in the development of geometrical figures, necessitates at least a brief reference thereto.

Let for brevity this quantity be denoted by i, and the complex quantity $(x + iy)$ be denoted by z, the part x being *real*, and the part iy, y times the imaginary i. We have seen that imaginary quantities can be represented upon an infinite lemniscate cylinder[2] when $z' = iy$ only, z' being a *line*. Suppose z however to denote merely the place of a point; this can be represented among other ways by "Argand's diagram,"[3] Fig. 30, or by Neumann's sphere:[4] x is the distance Ox, y the distance xz; and obviously

$$\rho \cos \theta = x; \ \rho \sin \theta = iy \ldots\ldots (33)$$

hence

$$z = \rho(\cos\theta + i \sin\theta) = \rho \operatorname{cis}\theta = \rho\epsilon^{i\theta} \ldots (34)$$



Real axis.
Fig. 30.

the last two being merely abbreviations of the first expression in (34). Suppose further, w to be a point dependent upon z, (regarded as an irresoluble quantity) in such a way that a single series of opera-

---

[1] See the left hand side of Fig. 20.

[2] See Fig. 4, § 13, formula (14), and footnotes 1 - 4, p. 246 and 1 p. 247.

[3] See footnote 4 page 246. Kühn's name ought to be associated with this diagram.

[4] See his Vorlesungen über Riemann's Theorie der Abelschen Integrale Leipzig, Teubner, 2° Edit. 1884. A sphere of unit diameter, was chosen by Neumann as the field or surface on which to represent the position of p. For an infinite or a large value of z, this method has advantages, but it is unessential to our present purpose.

tions upon z is adequate to determine the corresponding values of w;[1] then the representation on one plane of w, corresponding to an arbitrary series of values of z upon another, is known as its *conformal representation.*[2]

Consider such a representation of a simple function, as for example

$$w = z^n \ldots\ldots\ldots (35)$$

which with (34) gives

$$\rho_w = \rho^n ; \ \theta_w = n\theta \ldots\ldots\ldots (35a).$$

If the point z move continuously in its own plane, so that its path be any given figure, the conformal representation in the w plane is completely defined by this last equation. Such representation may be regarded as a very general[3] complex method of continuously generating geometrical figures, the function

$$f(w^n, z^m) = 0 \ldots\ldots\ldots (36)$$

defining the *type* of generative movement, which movement however does not acquire a determinate character until the figure represented by z is also specified.

34. *Riemann surfaces.*—In equation (36) denoting an irreducible algebraic equation, there will, for every value of z, be n values[4] of w, such a function is said to be *many-valued, multiform*, or *polytropic.*[5] A Riemann surface, is a surface such that the n-valued function can be schematically represented thereupon as a *single-valued* function.[6] In an expression, such as w = say $\pm \sqrt{z}$, we

---

[1] Such a function is called *monogenic;* the term was first used by Cauchy, who shewed by $w = f(x - iy)$ cannot be regarded as monogenic: *cf.* Grundlagen für eine allgemeine Theorie der Functionen einer veränderlichen complexen Grösse. Riemann, Ges. Werke.

[2] Conforme Abbildung. Gauss, Werke, Bd. IV., p. 262.

[3] Weierstrass however has shewn that monogenic functionality is not coextensive with arithmetical operations. Abhandl. aus der Functionenlehre, Ber. Akad. 1881, p. 90.

[4] See Puiseux's memoirs. *Liouville*, 1° Sér. t. xv. pp. 365, 480, 1850; t. XVI. pp. 228 - 240, 1851.

[5] If for a single value of z, w has only one value, independently of the way z acquired its value, the function is said to be *uniform, monotropic*, or *single-valued:* if it has in any way more than one value, *multiform, polytropic*, or *many-valued*—(eindeutig, mehrdeutig). A monogenic, uniform, and continuous function is said to be *meromorphic*, or *holomorphic*, or *synectic* over any *limited region* in which it possesses the indicated characteristics.

[6] An artifice that greatly assists the study of functions.

have, consistently with (33) to (35*a*), and denoting the quantities belonging to w by accents, $\rho' = \sqrt{\rho}$, $\theta' = \frac{1}{2}\theta$ or $\frac{1}{2}\theta + \pi$, that is to say, two numerically equal but oppositely directed values of w; which may be regarded, not as separate functions, but as the *branches* of a—in this case, two-valued—function. For example, if z describe a closed path passing through neither 0 nor ∞, *without* going round the origin, as in Curve 1 Fig. 31, θ' will have (in the instance mentioned) only half the range of the limit lines therein shewn, *i.e.* half the *amplitude* of θ. If z make one circuit, θ' will range through π only; but if z make two complete circuits, θ' will make a complete circuit 2π: or more generally—in this particular case—for an even number of circuits by z, the w curves will be closed, for an odd number they will not. Thus on sheets, lying indefinitely near one another but distinguishable, two series of values can be represented by a contir uous curve, provided that the sheets are so constructed that one ;an pass from one into the other, as indicated in Fig 32 (*a*).[1] In this figure, P is infinitesimally close to P′ but on the lower sheet; this passes *pseudo-continuously* at the cut or *branch-line*[2] 0 to ∞, (at which the sheets are joined) into the upper sheet. The nature of the junction is indicated in Fig. 32 (*d*), except that the distance between the lines is infinitesimal.[3] The sheets are joined at no other place than the branch line, not necessarily a straight line.

Various *branch-points*,[4] such as A and B, Fig. 32 (*b*), will be required according to the form of the function to be represented, *e.g.*:—$w = \sqrt{\{(z-a)(z-b)\}}$ would require a two sheeted-surface with a branch line, as in the figure, and a four-valued function, a

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[1] This is necessary since we can pass continuously from $+s$ to $-s$.

[2] Called also *branch-section* or *crossing-line*. (Verzweigungsschnitt—ligne de passage).

[3] It is obvious that the sheets are *not* parallel planes, and in passing from sheet to sheet we must move suddenly at right angles even if only an infinitesimal distance. The continuity is obviously only *pseudo-continuity*.

[4] Verzweigungspunkt oder Windungspunkt. The surface is known sometimes as a winding surface, and the branch-point of m sheets as a winding point of the $(m-1)$th order.

four-sheeted surface similar to Fig. 32 (*c*) and (*e*), O being the branch point.[1]

When surfaces other than planes are required, the nature of junction and passage from sheet to sheet is in all cases identical, *i.e.* by a line; sufficient however has been indicated to shew the characteristics of the scheme. Strictly it is not a realisable or possible scheme, as is evident if we remember that the infinitesimal is a real quantity not absolutely nothing, hence the surfaces are not really planes, spheres, etc., or if they were could not join in the manner required.[2]

35. *The connectivity of space.*—The connectivity of surfaces, of solids or of n-dimensional quanta, expresses the number of sections that must be made in order to divide them into two distinct *i.e.* simply connected parts. Consider Fig. 33 (*a*): it will be observed that its *edge* is continuous, and that it is *unifacial*, or *unilateral*,[3] and that starting at any point O, a single circuit in the direction of the arrow, terminates at the underside of O; a second circuit however returns to the starting point.[4] (This is the nature of supposed single elliptic space). Further we notice that Fig. 33 (*b*) has only one edge, and Fig. 33 (*c*) but one edge and face: it is therefore similar to (33*a*): a single circuit from O does not return thereto, but ends on the under-side.

The nature of the connectivity of surfaces and solids is by no means so obvious as might at first be imagined. If for example in Fig. 33 (*a*), representing a band of *uniform width*, (which has been turned through π so as to make it unifacial and single-edged, instead of cylindrical) a cut be started at A and kept a uniform

[1] See Holzmüller's Einführung in die Theorie der isogonalen Verwandschaften und der conformen. Abbildung, Leipzig 1882 (Teubner). The dotted lines will indicate the complete path from sheet to sheet.

[2] The movement from sheet to sheet does not introduce even infinitesimal error of the first order, with regard to the purpose of the representation: hence *practically* it is unexceptionable.

[3] If I mistake not, Möbius was the first to notice this fact. It may be mentioned that it has been suggested that the ordinary plane of projective geometry is unilateral! See Klein, Math. Ann., Bd. VII., p. 549.

[4] Hence if cut along the arrow path it will *not* be divided.

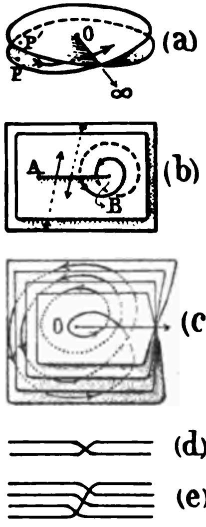

Fig. 32 a to e

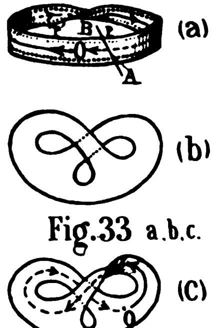

Fig. 33 a.b.c.

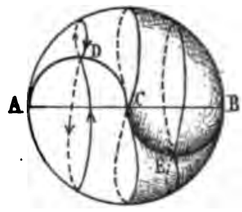

Fig. 34

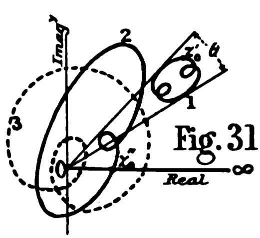

Fig. 31

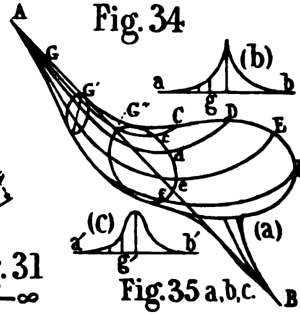

Fig. 35 a.b.c.

distance from the edge,[1] it will be found that the band is divided into twisted interlocked rings, one of which is identical with the original in length and twist, and the other is twice the length and is more twisted. A cut along the centre line from O returns into itself after one circuit, and does *not* divide the ring into two portions. A cut like AB makes it a *simply-connected*[2] surface. Fig. 33 (*c*) will exhibit similar peculiar features. A closed curve in an ellipsoidal surface will necessarily separate it into two simply-connected surfaces, whatever its position; in a tore or anchor-ring it may or may not do so, according to the position of the cut.

A surface like that in Figs. 33 (*a*) or (*c*) cannot, by extension, enclose space; if however the twist is 2π and it first interpenetrate its own surface, *then* by extension it can. Fig. 34 is a symmetrical

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[1] The cut is shewn by the dotted line. If traced the heavy dots denote the visible line, the light ones that on the remote side.

[2] That is one which every possible *cross-cut* from boundary to boundary will divide it into two parts.

figure illustrating a closed 3-dimensional space of such a type,[1] bounded by a surface of both positive and negative curvature: it suggests a type of space of more complex variety than either elliptic or hyperbolic alone.

Returning to the theory of representation on Riemann surfaces, the study of their deformation and connectivity have shewn that it is possible to transform the n-ply connected surface into a simply-connected surface by a series of dissections.[2] It is not proposed to discuss the connectivity or dissection of the surfaces; but it may be noticed that although they can never be of the character alleged, viz. planes, spherical surfaces etc., figures infinitesimally approximate thereto, can be generated continuously. In Fig. 32 (*a*) it is evident from the figure itself, that the line $0 - \infty$ can be spirally moved so that its path will be the required surface. The surface of Fig. 33 (*b*) can be continuously generated by the motion of lines from the points A and B and the line AB itself. The attempt at continuous generation will reinforce the recognition of their real departure from their ideal description.

36. *Conception of* n-*ply extended magnitude.*—Reference has already been made to Riemann's treatise on the hypotheses which lie at the basis of geometry, in which he affirms that that science *assumes as things given both the notion of space, and the first principles of constructions in space!* The entire argument is intelligible only if those notions be first admitted, *i.e.* if we are to be assumed capable of distinguishing in thought between straight and curved plane and spherical, and so on: but it is not intelligible; consequently no reason founded on such ideas can be adduced to

[1] Let a point p' be applied at p diametrally opposite, and imagine the interpenetration to be possible. The figure so 'formed' could be closed up into such a figure as 34, half of which only is shaded. Its cross section is a lemniscate of varying parameter.

[2] The matter has been discussed by Casorati, Clebsch, Clifford, Hofmann, Klein, Lüroth, Neumann, Prym, Schläfli and others. When all the winding points are simple, of a Riemann's surface with p sheets, of connectivity $2q + 1$, the surface can be so transformed that there will be a single branch-line between consecutive sheets excluding the last two, between which there are $q + 1$ branch lines. This surface is known as the canonical form for the case where all branch-points are simple.

overthrow them. Riemann's argument therefore can logically lead to nothing more than that we may, for sufficient reasons, regard the objective universe under the form of a specialised region of space, and if evidence were accumulated shewing that that view offered any advantages, a change of the ordinary scheme of interpretation might be desirable. The foundations of geometry however, would remain impregnable, and straight lines, planes, and the definitions of deviation would be no less necessary than they are now.

The special reason adduced for doubting the validity of our fundamental geometrical notions was that researches in respect of the quanta of definite portions of a "manifold"[1] of which tri-dimensional space is assumed to be a somewhat simple form—constituted merely a division of the science of magnitude, in which magnitudes are to be treated as regions in a manifold, not independent of their position. The absence of such researches was alleged to be the reason why the achievements of Lagrange, Pfaff, Jacobi, and Abel for the theory of differential equations remained unfruitful, but outside this, the researches were essential for the adequate discussion of multiform analytic functions (on the manner indicated in the preceding section). The Riemann surfaces have shewn that every system of points represented by a function, may, with an n-ply extended magnitude, be *represented* continuously, the manifold passing over continuously into one another, and hence the determination of position in a given manifold is reduced to the determination of quantity, and of position in a manifold of less dimensions, *i.e.* $n - 1$, when the original manifold is n-ply extended.

Riemann's doctrine affirms that to regard a straight line as by the equation

$$\delta s = \sqrt{(\delta x^2 + \delta y^2 + \delta z^2)} \dots\dots \dots (37)$$

is to constitute the simplest but not the essential type of possible

[1] "Mannigfaltigkeit."

spatial relationship.[1] With rigorous conceptions this expression however, denotes a uniquely straight line, for each element must be regarded as straight and at right angles, not on a spherical surface but absolutely (*i.e.* they must not be merely infinitesimal portions of curves): consequently the notion of an n-sheeted surface (assumed to be plane, but not really so) or of an n-ply extended magnitude of any other kind, throws no real light upon the constitution of what is popularly meant by space. A little consideration will shew that it is just because we *do* "assume with Euclid not merely an existence of lines independent of position but of bodies also,"[2] that geometry itself and mathematical thought has any validity. Once that basis is departed from, nothing is certain or valid; and not only do the conclusions of geometry fail, but the constructions and conclusions of analytical geometry fail also. Their logical basis is not a whit more assured than that of pure geometry: the certainty or uncertainty is of the same type. All ratiocination on the subject is unmeaning, and the apodictic certainty of the conclusions disappears, unless it is true that, in the words of Kant, "space is no mere empirical concept derived from external experience," nor "a determination produced by phænomena": "it is rather the "condition of their possibility," or, "a representation *a priori* which necessarily precedes" them.[3] The fact that schemes have been discovered by means of which analytical functions may be readily represented, though of great importance in the development of mathematical science, in reality establishes nothing of moment with regard to the *foundations* of geometry. When geometrical meaning is attached to algebraic or other symbols, the validity obviously depends upon the fundamental geometrical ideas assigned to them not to any consequences that flow therefrom.

[1] The next degree of simplicity according to Riemann is where the line element may be expressed as the fourth root of a quantic differential expression. The difficulty of the theory cannot be logically avoided by refusing to recognise the difference between δx, δy and δz as parts of straight lines or parts of curves.

[2] Riemann's treatise, III., § 1.

[3] See Kritik d. rein. Vernunft: transscend. Aesthetik 1er Absch. §2, 1.2.

37. *Illimitability of opèrative schemes for the generation of geometrical figures.*—It must now be evident that no limit can be assigned to operative schemes for the generation of specialised regions of space, or of geometrical figures either therein, or in ordinary, *i.e.* homaloidal space. The bizarre idea of the curvature of the latter, scarcely touches the fringe of the subject. Every type of geometrical figure, and every variation of it, can be made the subject of a special geometry, having its own peculiar features; and space can be so specialised as to be analogous thereto: that is to say a region of ordinary space can be constituted so that its analytical treatment, from some particular point of view, will be analogous to the special geometry referred to. To fix our ideas, suppose Fig. 34[1] to represent a double surface of both positive and negative curvature:[2] its geometry would present all the features of "elliptic" and "hyperbolic space," passing continuously from the one to the other.[3] The surfaces cross one another at right angles at the curved line ADCEB.[4] It will be at once recognised that the geometry of this continuous interpenetrating surface will present remarkable features. Still more remarkable would be the geometry of the type of surface represented perspectively in Fig. 35, which may be generated as follows:—

On the straight line AB let a quadric surface perpendicular to the line (say an ellipse) move along it from A to B, so that the terminal of one diameter remains on the line, this diameter however, both turning round AB and altering its dimensions as the surface in which it lies moves along.[5] The successive values of the principal diameter might be represented by the ordinates of either of the curves, Figs. 35 (*b*) or 35 (*c*); or by those of curves of higher degree. A surface of this type can be so constructed

[1] Only one half of the figure is shaded.

[2] The section perpendicular to AB shews two semi-lemniscates of different parameters except at C where they are equal.

[3] Consequently Helmholtz's sphere-dwellers would, according to his view, conclude that *parallel* lines, both *converged* and *diverged!*

[4] Also that straight lines may intersect at right-angles!

[5] The surface may be supposed to increase its area, and the ratio of the diameters to change.

as to exhibit the features of elliptic, parabolic and hyperbolic geometry,[1] and is moreover tortuous.

These surfaces have been designed merely to illustrate how easily, and in what an illimitable number of ways space can be specialised, and that for such space special geometries may be created. If the intensity of the surfaces in these figures be also varied the geometries may be still further complicated.

The constants of space of positive curvature may, as an abstract question, be of any magnitude whatever, consequently if the view that space may be positively curved were correct, it is a possibility that ordinary space is the locus of an infinity of *unbounded* curved "spaces."[2] It is equally possible also, that it consists of an infinity of "spaces" which are of the complex type roughly sketched or of more complex type still. The over-sublety of the conception would sufficiently argue its inutility as a foundation for geometry, even if it could be shewn to be consistent.

38. *Pangeometry.*—Non-euclidean- and pan-geometry have generally been regarded as practically identical. Much of what has been assigned these names is, as I have endeavoured to shew, really a geometry, not of space, but of specialised regions of space, analogous in some features to the geometry of curved surfaces. The true homaloid or continuum of three dimensions, *i.e.* space in the vulgar sense, is the foundation element of all spatial conceptions; and its dimensionless point, its straight line *without* breadth and thickness, its plane surface *without* thickness, its isotropy and homogeneity, are the fundamental forms which render any geometry intelligible, and which make possible a consistent study of its various specialisations. The bizarre idea that space may be *discovered* to be anything different from a homaloid, is really self-

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[1] G, G′, G″ are successive positions of the generating surface AB, AC, AD, AE, AF, etc., join corresponding points on the generatrix. Helmholtz's sphere-dweller, if on this surface, would conclude that parallel lines may be parallel, diverge or converge. If he supposed to perceive intensity as he looked along a line, the straight lines would be unique in that respect.

[2] That is spatial regions, each "*unbounded.*"

contradictory,[1] for it is on this essentially simple homaloidal concept that every other must be grounded. One may say further that this conception is our mental standard of reference, by means of which the differences of other conceptions are to be discerned, and is not affected by the fact that in physical applications, or in actual lines in the objective world, we never know how far the relativity of things limits our interpretations. In mathematical science the doctrine of relativity is of no moment *in so far as the fundamental conceptions are concerned.*

Ordinary space then may be regarded as really the locus of all possible determinate geometrical figures, and the domain of all spatial specialisations, susceptible of geometrical definition. The variety not only of these possible figures, but also of the possible *types* of figures, is probably illimitable, or at least is limited only by our failing to perceive them. And similarly the number of modes in which space may be specialised is also probably illimitable. The great reach of *projective* geometry as compared with *metric*, suggests that an extension in that direction will not be unfruitful. A geometry—which will aim at treating broadly the generation of complex geometrical figures by means of simpler ones, which will exhibit the limits of theorems respecting plane figures when those figures are constructed upon surfaces, which will shew the relationships of plane or solid figures when referred to rectilinear or to curved axes, which will in fact generalize geometry to the last possible extent—would be well worthy of the name "pan-geometry." Many of the splendid results obtained by the great mathematicians who have given some support to the remarkable

[1] Newcomb states that "there is nothing within our experience which will justify a denial of the possibility that the *space* in which we find ourselves may be curved in the manner here supposed," *i.e.* in the 4th dimension. See Crelle's Journ. f. reine und Angewandte Mathematik, Bd. LXXXIII., 1877. The title of Newcomb's treatise is "Elementary theorems relating to the Geometry of a space of three dimensions, and of uniform positive curvature in the 4th dimension. Space is evidently regarded as an object, not as the locus of objects. If a region were discovered in which the angles $A + B + C = \pi \pm \epsilon$, we could define a curved surface in it, in which $A' + B' + C'$, the vertices of the triangle being the same, would be π. Which are we to rely on, the straightness of the line or the sum of the angles?

theory of curved space, are really conquests in this field, and only require to be dissociated from the space-theory to be seen as such. Non-euclidean as a descriptive adjective hardly conveys the right idea of this higher general geometry; while the term "Pangeometry" does define its essential character. This geometry is not opposed to euclidean, but is a supplement of its field, the the narrowness of which has been exposed by the magnificent researches of modern mathematicians.

SOME THEOREMS CONCERNING GEOMETRICAL FIGURES IN SPACE OF n-DIMENSIONS, WHOSE $(n-1)$ DIMENSIONAL GENERATRICES ARE n^{ic} FUNCTIONS OF THEIR POSITION ON AN AXIS, STRAIGHT, CURVED OR TORTUOUS.

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1. Problem defined.
2. Form of graph of generating function immaterial.
3. Oblique rectilinear ages.
4. Generating function with curvilinear axes.
5. Rotation of generatrix obliquely about the t-axis.
6. Curvature of the principal, *i.e.* the t-axis.
7. Tortuosity of the principal axis.
8. Theory of equivalent generatrix of unit value.
9. Necessary number of equidistant values of equivalent generatrix.
10. Conclusion.

1. *Problem defined.*[1]—Whenever a finite quantity V_t in n-dimensional homaloidal space, generated by the motion of an $(n-1)$-

[1] The problem discussed may be read as a continuation of a previous paper, entitled, "On the relation, in determining the volume of solids, whose parallel transverse sections are n^{ic} functions of their positions on the axis, between the number, position, and coefficients of the sections, and the (positive) indices of the functions." See Journ. Roy. Soc., N.S. Wales, Vol. XXXIV., pp. 36–71. The z axis in that paper is for obvious reasons denoted by t in this.

dimensional homaloidal quantity in a direction parallel to the t axis of the former, can be expressed by the equation

$$f(x,y,z,w, \text{etc.}) = A_t = A + Bt^p + Ct^q + Dt^r + \text{etc.} \ldots\ldots\ldots (1)$$

in which the coefficients A, B, C, etc., have any real, finite values, positive or negative including zero, and the indices p, q, r, etc., are real and greater than -1, but may be either fractional or integral; then this n-dimensional quantity, for the limits 0 to t, will be

$$V_t = \int_0^t A_t dt = t\left(A + \frac{B}{p+1}t^p + \frac{C}{q+1}t^q + \frac{D}{r+1}t^r + \text{etc.}\right) \ldots\ldots (2)$$

The condition that V_t is to be finite for all values of t from 0 up to but not inclusive of $+\infty$ obviously requires that the indices lie between, but shall not include, -1 and $+\infty$, for supposing A_t to have a term $I\,t^{-1}$, its integral, being $I \log_e t$, will be ∞ for $t = 0$,[1] and this marks the inferior limit at which the function V_t becomes infinite for a finite index.

I propose to investigate the range and generality of the functions (1) and (2), and to develope certain theorems concerning their relations, when p, q, r, etc., are subject to the one restriction that they shall be greater than -1, and the axis t is *not* necessarily rectilinear.

2. *Form of graph of generating function immaterial.*—Except in so far as the interpretation of the integral is concerned, the form of the generating $(n-1)$-dimensional function is immaterial: so also is the angle of its inclination with the t axis, if this last be rectilinear. That this is so, will be evident from the following considerations. If the function be *essentially* one-dimensional, $f(x)$ say, its *graph* may be not only a straight line, but also a plane-curved, or plane-spiral line, a closed curve, or a series of any or all of these. So also it may be the intercept, parallel to the x-axis, between two curves, or the intercepts between any series of curves extending in the direction of the t-axis assumed to be rectilinear;

[1] A negative index $-m$ say, makes the *graph* of the function Kt^m an m^{ic} hyperbola, and consequently infinite for $t = 0$, while if m be positive the graph will be an m^{ic} parabola, and finite for zero or finite values of t.

the only necessary condition being that the *total* length of the lines, straight or curved, shall vary with t as assumed in (1). The essentially two-dimensional integral would then be *represented* by the total surface generated by the motion of $f(x)$ along the axis t, overlapping, should it exist, being taken into account.

Similarly if the generating function be essentially two-dimensional $f(x, y)$ say, it may be a plane surface, or a series of such of any form whatsoever, provided only that its, or their, total varies with t as expressed by the function A_t; and the function V_t will accordingly be represented by the volume—in right-cubic or parallelepipedic units, according as the system of axes is rectangular or oblique—of the path or paths of the former. Overlap, if existent, must as before be taken into account, which fact being quite general need not be further referred to.

Again, if motion in the axis t imply some variation in physical condition[1] of the surface or surfaces A_t, dependent merely upon its or their total area, *i.e.* independent of the *order* of the surface or surfaces, then it or they, though actually three-dimensional, may be regarded as *essentially* two-dimensional.

Similarly also, the function V_t will represent the integrated effect due to the motion along the axis t, or to rotation through the angle t, or to the lapse of time t, of any three-dimensional figure subject to such change of form or condition as may be expressed by (1). Analogous illustrations will serve to elucidate the nature of the integral, applied to space of higher dimensions.

It is evident that not only all the regular forms ordinarily considered in plane and solid geometry are included in the range of the function, but also very many others, and that its applications are not restricted to ordinary or tri-dimensional space.

3. *Oblique rectilinear axes.*—If the axis x, of the generatrix, and the axis t, be not orthogonal, the units of the generated surface will be oblique, hence if x make an angle ω with the plane perpendicular to t, its projection-length thereon will be $\cos\omega$,

[1] *E.g.* variation of intensity, see Journ. Roy. Soc., xxxv., pp. 284 - 286.

which therefore is the factor for converting the oblique into square units. So also, if $A_t = f(x, y)$, and the angle between these axes be $\frac{1}{2}\pi \pm \omega'$, and between the x, y plane and the t axis be $\frac{1}{2}\pi \pm \omega$, the factor to reduce the parallelepipedic to right-cubic units will be $\cos \omega \cos \omega'$; and similarly if $A_t = f(x, y, z, w,$ etc.), the inclinations being $\frac{1}{2}\pi \pm \omega, \omega', \omega'', \omega'''$ etc., one of these being in relation to the axis t, the factor of reduction k for the n-ply oblique units will be

$$k = \cos \omega . \cos \omega' . \cos \omega'' . \text{ etc} \ldots\ldots\ldots (3).$$

It is here assumed that the axes do not rotate about the axis t.

4. *Generating function with curvilinear axes.*—If the axis t be rectilinear, and x either rectilinear or curvilinear *in a plane orthogonal with* t, the one-dimensional generatrix is subject to no restriction except linear conformity to (1). Thus it may rotate about the t-axis, as is evident from the consideration that the element of surface $\delta V_t = \delta A_t \, \delta t$ is not affected by the direction of motion in relation to a line coaxial with that axis and lying in the plane containing the element; since the generated helicoidal element of surface is diminished in rectangular width, in exactly the same ratio as it is increased in length by the rotation.

An identical consideration indicates that the element of volume δV_t generated by the motion of the surface-element $\delta A_t \delta t$ is not affected by rotation about the t-axis, whether the units of surface be square, oblique, or are curvilinearly orthogonal or oblique, provided only that they remain constant in kind. This is clearly quite general, so that we may substitute 'n-dimensional homaloidal element' for 'element of volume,' and '$(n-1)$-dimensional homaloidal element' for 'surface-element,' in this last theorem.

5. *Rotation of generatrix obliquely about the* t-*axis.*—If the generating element lie in a plane *not* orthogonal with the t-axis, and not rotating about that axis, then an element of surface generated by linear element, will, when reduced to square units, be $\delta V_t = kA_t \delta t$, in which k is constant *only* for parallel directions in the plane, or rather for two series of parallel directions, whose axes of symmetry are the directions which give the maximum

and minimum values of k. If this plane make an angle of $\frac{1}{2}\pi \pm \omega$ with the t-axis, then k, for any line therein making an angle ξ with that direction which is perpendicular to t,[1] will be

$$k = \sqrt{(1 - \sin^2\xi \sin^2\omega)} \dots\dots\dots (4)$$

from which it is evident that, in general, the generating element is not free to rotate about the axis t, since k varies with ξ unless $\sin^2\omega = 0$, that is unless the axis of the generatrix-plane, or the generatrix system of axes, is orthogonal with t. It is therefore essential that the mean value of k, k_0 say, should be constant for every value of t, that is to say we must have

$$k_0 = \frac{1}{A_t} \Sigma (k\delta A_t) = \text{constant} \dots\dots\dots (5)$$

This condition will be satisfied if the projections of the linear figure or figures A_t for successive values of t, on a plane perpendicular to the t axis, are either homothetic, or are similar and similarly oriented with respect to the axes of the plane of projection. If the generating function represent a circle or a series of circles, its or their motion is unrestricted, because they will project as ellipses with parallel axes in the ratio $\cos\omega : 1$; but if it represent the perimeter of a polygon or indeed any other figure than a circle—or a series of such—it or they must not change its or their orientation, with respect to the plane of the axial-inclination ω, though otherwise unrestricted as to movement. Rotation in the plane of the generatrix involves in general therefore an opposite rotation of equal amount, of the rotated lines or figures about their own axes, in order to satisfy condition (5).

The necessity for imposing this condition is a consequence of the fact that motion, in the plane of a generatrix, oblique to the axis of generation, (t), is essentially an unequal variation in the rate of motion in the latter, of the several elements of the generating function: the condition that the projections shall be either homothetic, or similar and similarly oriented, involves essential uniformity in the motion, of the generative elements, in the direc-

[1] That is with the line of intersection with a plane perpendicular to the t axis.

tion of the axis of generation. This last is the characteristic condition.

If A_t be two-dimensional, $f(x, y)$ say, the x and y axes, or systems of axes, straight or curvilinear, lying in a *non-rotating* plane inclined at any angle $\frac{1}{2}\pi \pm \omega$ with the rectilinear t-axis, then to determine in cubic units the generated volume V_t, it is necessary only to multiply by $\cos \omega$, if the generatrix be expressed in square units; consequently the position of, or any change of position in, the generating elements is immaterial.

6. *Curvature of the principal,* i.e. *the* t-*axis.*—Subject to certain restrictions the axis t may be a plane curve, a tortuous curve or curve of double curvature, or more generally a curve of n-ple curvature. Let the radius of the *osculating circle* at any point in the curve, first of all assumed to be *plane*, be denoted by ρ. Then in order to be unequivocally specified, the abscissæ of the generating line or lines must, whether rectilinear or curved lie in this radius, or the radius produced, or in the plane containing the radius and orthogonal to the plane of the curve, the surface generated by any element δx or δs, rectangularly distant $\Delta\rho$ from an *axial-surface*, defined by the path of curved axis t itself, moving perpendicularly to its own plane, (or, what is the same thing, by the sheaf of lines drawn through the axis t, continually perpendicular to the plane in which it lies)—will be greater than that generated by an element of the same length in this axial-surface, in the ratio 1 to $(1 + \Delta\rho/\rho)$, which ratio will be a factor of correction. Hence in order that the correction involved by the curvature of the axis (and consequently of the axial-surface) shall disappear, it is necessary that

$$\Sigma\,(\delta s\,.\,\Delta\rho) = 0 \;\ldots\ldots\ldots (6)$$

for every value of the abscissa. That is to say the centre of inertia of the system of lines must lie continually in the axial-surface as defined.

Subject to certain further restrictions the axial-surface may also be *oblique* to the curve, that is to say in generating this surface the direction of the path of every point on the curve may be

identical, and make an angle of $\frac{1}{2}\pi \pm \omega$ with the plane of the curve itself. In this case planes parallel to the plane of the curve, intersect the surface in curves identical with the curved axis itself. The plane, containing both the radius of the osculating circle at any point in the curve, and the path of this point when generating the *oblique-axial-surface*, determines unequivocally the abscissa of the generatrix; and this plane, the radius and radius produced, and the path of the point, constitute what may be called the *abscissa-plane* and the axes of reference thereon. It is at once obvious that at least condition (6) must be satisfied as the generatrix moves along the axis, the planes of the osculating circles in which ρ is measured being taken always parallel to the plane of the curved-axis t, for each point in the plane of generatrix, and for every position on the axis. This condition alone is, however, inadequate.

The surface generated by an element of the generatrix (δs) parallel to the radius of the osculating circle, is greater than that generated by an element of equal length, parallel to the other axis of the generatrix-plane, each being equidistant from the centre of that circle. Consequently in order that the constant k, of reduction for obliquity, shall be identical for every point on the t-axis, the successive figures on the plane of the generatrix, as it moves along the axis must be homothetic with respect to the axes of that plane,[1] even when the inclination of such axes is identical. This inclination however changes as the plane moves along the axis, since it is a function of the angle ω' between the tangent to the curved-axis t and the orthogonal projection, on the plane thereof, of the line (making the angle $\frac{1}{2}\pi \pm \omega$ with the plane) which generates the oblique axial-surface. Let ω'' denote the excess or defect from 90° of the angle between the axes on the abscissa-plane;[1] then evidently

$$\sin \omega'' = \sin \omega \sin \omega' \quad\ldots\ldots\ldots(7)$$

In this expression ω is constant, but ω', and therefore ω'' also, are

[1] So that the inclination of the XY axes, XPY say, would be $\frac{1}{2}\pi \pm \omega''$, or they may be similar and similarly oriented.

variable. The projection of the X axis (PX say), on the plane perpendicular to the radius of the osculating circle, *i.e.* the Y axis (PY say), makes an angle $\frac{1}{2}\pi \pm \omega'''$ with the intersection of the plane of osculation therewith, the angle ω''' being given by the equation

$$\tan \omega''' = \tan \omega \cos \omega' \ldots\ldots\ldots (8).$$

The factors for reducing an element δs of the generatrix at right angles to the axis PY is $\cos \omega'''$; or if the angle made by the direction of this element with the Y axis be denoted by β, the reducing factor (k') is the sine of the angle of inclination (χ) between the direction of δs and that of the tangent to the curved axis t at the abscissa-plane in which δs lies. This is given by the expression[1]

$$k' = \sin \chi = \cos \beta \sqrt{(1 - \tan^2 \beta \cos^2 \omega''')} \ldots\ldots\ldots (9)$$

hence the mean value of k', k'_0 say, for each successive position of the generatrix must be constant, and the condition expressed in equation (5) therefore hold good.[2] The necessity for simultaneously satisfying conditions (6) and (5a) say, indicates how greatly the oblique relation, of the axial-surface with the plane of the t-axis, complicates the issue for a 1-dimensional generatrix. It is otherwise when the function is 2-dimensional, that is when $A_t = f(x.y)$, a case we now proceed to consider.

First suppose the axes of the plane surface A_t, continually perpendicular to the plane of the t-axis, to be rectangular, one axis being the radius of the osculating circle: then (6) is the only condition to be satisfied, δs becoming $\delta x.\delta y$. If the plane of the generatrix has the oblique relation previously defined, the generated volume has simply to be reduced by multiplying by $\cos \omega$, and a condition similar to (6) has alone to be satisfied, $\Delta\rho$ being interpreted as in the preceding case, that is to say it is to be always measured in a line parallel to the plane of the curved t-axis. The element δA_t of the generatrix being however $\delta x.\delta y.\cos \omega''$, see formula (7), the value of the generatrix is not simply $f(x.y)$

[1] It may be noticed that if $\omega''' = 0$, k is unity, as it should be, for all values of β.

[2] We may call this condition (5a).

independent of the inclination of the axes, but taking equivalence of area in rectangular units into account; hence

$$\delta A_t = f(x, y, \omega'') \; ; \quad \Sigma\,(\delta A_t \, . \, \Delta\rho) = 0 \ldots\ldots\ldots (10)$$

indicates the conditions.

The case of curved axes in the generatrix leads to more complex conditions, and may be dismissed without consideration, as of little practical moment.

We now consider the case where the t-axis does not lie in a plane.

7. *Tortuosity of the principal axis.*—Let the axis be a tortuous instead of a plane curve; and the surface formed by the sheaf of lines drawn, through every point of the curve, perpendicular to the plane of the osculating circle thereat, be called the *binormal axial-surface*;[1] and let also the plane, perpendicular to the osculating circle and containing its radius, be called the *normal plane;* then the line of intersection of 'normal plane' and the 'binormal axial-surface,' and the radius and radius produced of the osculating circle, are rectangular axes, at the intersection of which the tortuous curve[2] is everywhere perpendicular. The normal plane, and the axes thereon, are consequently the analogues respectively of the plane perpendicular to a rectilinear axis, and the rectangular axes thereon; and are also respectively analogous to the plane continually perpendicular to the tangent of a plane curve, and axes thereon; one of which is the radius of the osculating circle, and the other the vertical to the plane of the curve. We shall therefore, as before, call it the abscissa-plane.

The circular curvature uniquely defines the curvature of tortuous curves, inasmuch as the planes of osculation pass through any three consecutive points, infinitesimally separated. And again, the locus of the centres of circulation curvature, are defined by the point, where the line of intersection (or *polar line*[3]) of two

[1] This will of course, not be identical with the 'rectifying developable.'

[2] Or its tangent.

[3] The locus of the polar lines is the *polar developable*, *i.e.* the centres of circular curvature lie on the polar developable.

consecutive normal planes, infinitesimally separated, cuts the plane of osculation to which it is perpendicular. It follows therefore that the perpendiculars to the osculating planes at two consecutive points on a tortuous curve, are analogues of the parallel perpendiculars to the plane of a plane curve. That is to say, they will be everywhere equidistant from the plane perpendicular to the tangent of the curve[1] at a point midway between the points. Orthogonally projected on that plane however they will make an angle equal to $d\phi$ the *angle of torsion* for the length dt of the curve.[2]

As before, let ρ denote the radius of the osculating circle, that is the *radius of circular curvature.* Hence we shall have

$$dt = \rho \, d\theta \ldots\ldots\ldots (11)$$

where $d\theta$ is the *angle of contingence*, or angle in the plane of osculation between two consecutive tangents at points dt apart.

If also we have

$$dt = \sigma d\phi \ldots\ldots\ldots (12)$$

σ is what may be called the *radius of torsion*, $d\phi$ being, as before mentioned, the angle of torsion.[3]

If the generatrix be essentially one-dimensional, *i.e.* if it be a line, the surface generated will depend upon the angle it makes with the axes on the abscissa-plane, and upon its position on that plane.

---

[1] Containing therefore the radius of the osculating circle.

[2] These propositions will perhaps be more obvious when it is remembered that a tortuous curve is *misdescribed* when called a curve of *double* curvature. Its essential character is better understood by regarding it as a curve of circular curvature, the plane of which however, twists about the tangent to the curve at each point, instead of remaining constant as in a plane curve.

[3] The rotation of the axis formed by the line of intersection of the binormal axial-surface, and the normal plane, or, what is the same thing, the rotation of the plane of osculation, is $d\phi$ in the distance dt. This is equal to the angle of contingence of the *edge of regression* of the polar developable for the corresponding points. The radius T, of what may be called the *complex curvature* is given by

$$1/T^2 = 1/\rho^2 + 1/\sigma^2,$$

consequently

$$dt = T d\psi,$$

if $d\psi$ be the *angle of complex curvature*. Further

$$(d\psi)^2 = (d\theta)^2 + (d\phi^2)$$

Consider first an element δs parallel to, but not necessarily on the y axis, (*i.e.* the radius of the osculating circle and its prolongation): this will generate an element of surface $\delta s \, . \, \delta t \, (1 + \Delta\rho/\rho)$ whatever be its position.[1] An element δs on the x axis lying in the binormal axial surface and coincident therewith, will generate a surface the magnitude of which, depending upon its distance $\Delta\sigma$ from the plane of osculation, is since $d\phi = dt/\sigma$, easily seen to be $\delta s \, . \, dt \, \surd\left\{1 + (\Delta\sigma/\sigma)^2\right\}$. If however it is parallel to the x axis, and distant $\Delta\rho$ therefrom, the generated element will become $\delta s . \delta t \, \surd\left\{(1 + \Delta\rho/\rho)^2 + (\Delta\sigma/\sigma)^2\right\}$.[2] For brevity let $\Delta\rho$ or y, divided by ρ, be denoted by λ, and similarly $\Delta\sigma$ or x, divided by σ, be denoted by μ; so that λ and μ are *ratios* merely; then for any element δs, making the angle γ with the x axis, and whose rational coordinates are λ and μ, we shall have for the generated surface δA_t,

$$\delta A_t = \delta s \, . \, \delta t \, \surd\left\{(1 + \lambda)^2 + \mu^2\right\} \sin \eta \, \ldots\ldots\ldots (13)$$

η being the angle of inclination between δs and the element of surface it generates. Let ζ denote the angle made by any point in δs with the radius of osculation as it moves subject to the torsional as well as the onward motion: then $\tan \zeta = (1 + \lambda)/\mu$ and since

$$\cos \eta = \sin \gamma \cos \zeta = \mu \sin \gamma / \surd(1 + 2\lambda + \lambda^2 + \mu^2) \ldots\ldots\ldots (14)$$

equation (13) may be written

$$\delta A_t \equiv \kappa . \delta s . \delta t \equiv \surd\left\{(1 + \lambda)^2 + \mu^2 \cos^2 \gamma\right\} \delta s . \delta t \ldots\ldots\ldots (15)$$

which resolves into the quantities previously mentioned for $\gamma = 0$ and $\gamma = 90°$. It is evident from this last equation, seeing that $(1 + \lambda)^2$, μ^2, and $\cos^2 \gamma$ are necessarily always positive, that the value of κ cannot be made unity by the imposition of any condition whatsoever in the case of a closed curve; for any variation with t would involve changes in λ and μ. For a line, curved or straight, it is necessary that $\Sigma\left\{(1 + \lambda^2) + \mu^2 \cos^2 \gamma\right\} ds$ should conform to (1) throughout. We may therefore say that there is no *general* condition by means of which the generated quantum can be made to

[1] That is to say, the element of surface is independent of its distance from the y axis.

[2] It may be noted that the torsional component depends upon $\Delta\sigma$ alone, not at all on $\Delta\rho$.

conform to the fundamental equation, where the generatrix is one-dimensional.

When the generatrix is two-dimensional, it is quite otherwise. The value of $\Delta\sigma$ no longer affects the generated elements, the volume thereof depending upon $\Delta\rho$ alone, that is to say,

$$\delta A_t = \delta x . \delta y . \delta t \ (1 + \Delta\rho/\rho) \ \ldots\ldots\ldots(16)$$

in all cases, hence

$$\Sigma\,(\delta A_t \,.\, \Delta\rho) = 0 \ldots\ldots\ldots(17)$$

is the only condition to be satisfied; *i.e.* the centre of inertia of the generatrix must lie continually in the binormal axial surface.

8. *Theory of equivalent generatrix of unit value.*—It has been shewn herein, that when the t-axis is curved or tortuous, the mean value of the factor $(1 + \Delta\rho/\rho)$ must, for every position of the generatrix, be continually unity; otherwise some correction to the integral will be required. Let us suppose however, this condition to be abandoned, and the mean value (depending upon the place of the centre of inertia of the generatrix elements or area) to vary in such a manner, that this variation is also a function of the position of the generatrix on the axis, such as may be represented by the expression

$$k' = k + ft^{a} + gt^{b} + ht^{c} + \text{etc.} \ldots\ldots\ldots (18)$$

We shall then have, for the value of what may be called the *equivalent generatrix, the factor of which will be unity*, for every position on the axis,

$$A_t' = kA_t + A\,(ft^{a} + gt^{b} + \ldots) + B(ft^{a+p} + gt^{b+p} + \ldots)$$
$$+ C\,(ft^{a+q} + \ldots) + D(ft^{a+r} + \ldots) \ldots\ldots\ldots(19)$$

which, when a, b, c and p, q, r are actually given can be arranged according to ascending values of the indices, and written in a form identical with the original expression (1), viz.

$$A_t' = A' + B't^{p'} + C't^{q'} + D't^{r'} + \text{etc.} \ldots\ldots\ldots(20)$$

the integral of which will be therefore the same as (2) in form.

9. *Necessary number of equidistant values of equivalent generatrix.*—I have shewn elsewhere[1] that the prismoidal formula

[1] Some applications and developments of the prismoidal formula.—Journ. Roy. Soc., N. S. Wales, Vol. XXXIII., pp. 129–145, 1899. See §§ 15, 16.

rigorously applies to solids bounded by what may be called "circularly warped surfaces," in which the centre of inertia of any section (formed by a plane rotating about an axis and cutting the solid) changes its distance, from the rotation axis, linearly[1] in relation to the arc through which the section turns. It will now be shewn that this is an elementary case of a much more general theorem.

If the terminal values of a generating function of the form,

$$A_t = A + Bt + Ct^2 + Dt^3 + \text{ etc.} \ldots\ldots\ldots (21)$$

together with a series of equidistant intermediate values, are given, the generated quantum, between the limits t_1 and t_2, is absolutely determined, when the highest index in the generatrix, (1), is the same as the number of given values inclusive of the terminal ones, if the number is odd, or one less than the number, if it is even[2] Consequently if the indices p, q, r, etc. and a, b, c etc., are positive integers, that is to say, if the quantum of the generatrix and of the departure of its centre of inertia (in the direction of the radius of curvature) from the axis, are both positive integral functions of the position thereupon, then it is easy to determine the number of equidistant values of the generating function necessary to fix the quantum of the generated figure. For let m denote the sum of highest indices, $s + d$ say, then if an odd number be taken, if must be m, but if an even, $m + 1$.

10. *Conclusion.*—Since an expression of the form (1), can be designed to represent, even with a few terms in most cases, almost any spatial quanta related to a variable, it is evident from the foregoing consideration of the curvature of axes, that the generality

[1] Such a figure for example, as a railway cutting on a circular curve, when the slope of the natural surface changes at a uniform rate with respect to a line rotating about the rotation axis at the centre of the curve.

[2] See my paper "On the relation, in determining the volumes of solids, whose parallel transverse sections are n^{ic} functions of their position on the axis thereof, between the number, position, and coefficients of the sections, and the (positive) indices of the functions."—Journ. Roy. Soc., N. S. Wales, Vol. xxxiv., pp. 36–71 1900. § 18.

it is calculated that $C = \cdot 67536$ (Dana $\cdot 67232$). A stereographic projection on the plane (001) is given.

For the sake of comparison, the elements for a monoclinic crystal of the same form are given, taking the long axis vertical,

$$a : b : c = \cdot 69248 : 1 : \cdot 67900. \quad \beta = 124^\circ\ 2'$$

The length along the	pseudo-clinodiagonal	a :	5·75 mm.
,, ,,	pseudo-orthodiagonal	b :	8·75 mm.
,, ,,	pseudo-vertical axis	c :	13·5 mm.

The stereographic projection of such a crystal on the plane (100) is also given. The pseudo-monoclinic habit is produced by the excessive development of two faces meeting in a polar edge and the simultaneous development of the two faces parallel to them. This form of distortion has not been noted by Dana, either for cassiterite or the isomorphous form of TiO_2, rutile. Traces of oscillatory combination with the prism [110] are indicated by a striation parallel to the long edges.

The pseudo-rhombic modification is of somewhat less interest than the above since a similar distortion in the case of rutile is mentioned by Dana, though. so far, I have found no description of it in the case of cassiterite. It is the result of excessive development of alternate instead of adjacent faces at one of the poles of the crystal, and of the parallel faces at the other pole. In this case of the pseudo-rhombic crystal the faces of the pyramid of the second order [101], those of the prism of the first order [110] and the basal planes are noticeably developed, forming the pseudo-pyramid and pseudo-pinacoidal faces in the distorted crystal.

Lévy and Lacroix (Les Mineraux des Roches, p. 119) describe artificially formed hexagonal double oxide of tin and platinum containing

Sn	57·94
Pt	22·48
O	19·58
	100·00

and with a specific gravity of 6·70. The crystals form flat hexagonal plates and are optically negative. As the cassiterite from

DISTORTED CRYSTALS OF TINSTONE

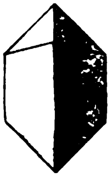

FIG 1

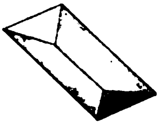

FIG 2

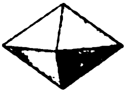

FIG 3

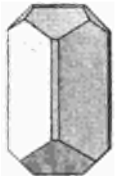

FIG 4

(*b*)

(*c*)

(*a*)

Pilbarra occurs intercrystallised with monazite it is quite possible that it may contain a certain proportion of some of the rare earths. This may account for the distortion of the crystals.

A cross section of one of the rather imperfect pseudo-monoclinic crystals is dark reddish-brown, almost opaque, and shows under the microscope the fine lamellar twinning characteristic of cassiterite, parallel to the faces of the second order pyramid [101]. The specific gravity at 16° C. determined by means of the pycnometer is 6·876. Before the blowpipe with $Na_2\ CO_3$, abundant globules of tin are obtained with ease. Fused with Na_2CO_3 and sulphur, and dissolved in hot water, an abundant yellow precipitate of Sn_2S_3 is obtained on addition of HCl.

Explanation of Plate and Figures.

(*a*)—Photograph of a pseudo-monoclinic crystal of tinstone.
(*b*) (*c*)—Photograph of a pseudo-rhombic crystal of tinstone.
Fig. 1—Figure of pseudo-monoclinic crystal in the conventional position for reading as a monoclinic crystal.
Fig. 2—Same, in conventional position as tetragonal crystal.
Fig. 3—Faces of tetragonal pyramid with its faces in equipoise.
Fig. 4—Figure of pseudo-rhombic crystal in the conventional position for reading as a rhombic crystal.
Fig. 5—Stereographic projection on the basal plane, indicating the tetragonal symmetry of the crystal.
Fig. 6—Stereographic projection as a monoclinic crystal on the apparent orthopinacoid.

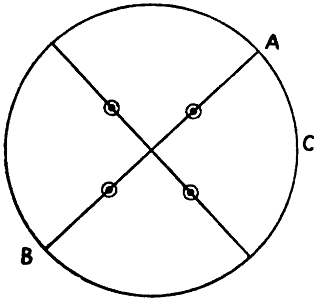

FIG 5

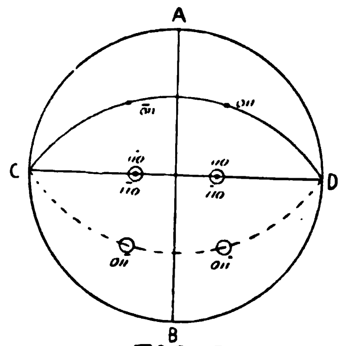

FIG 6

CURRENT PAPERS, No. 6.

By H. C. RUSSELL, B.A., C.M.G., F.R.S.

[With Diagram.]

[*Read before the Royal Society of N. S. Wales, November 6, 1901.*]

THE interest taken in these current papers is steadily increasing and becoming more and more valuable as an index of the chief currents, as well as some unusual currents; as for instance a current paper thrown over, off the south coast of Africa was found in latitude 31° south, on the coast of South America. All previous drifts in that ocean which have come before me have been to the *east*—current papers and also icebergs. I am beginning to find evidence of most important and great currents of water and atmosphere, that are of the greatest value for meteorology.

For instance, in 1895, persistent north-west winds over Australia altered the ordinary drift of current papers, and at the same time did great damage on shore. On the east coast of Australia strong currents from Tasman Sea and New Caledonia have taken the bottles into the neighbourhood of Torres Straits; the same drift is evident in the track of the steamers from Sydney to Canada. This proves the existence of the same general drift as that I have been recording in the Indian Ocean for several years; and is the evidence of the great westerly drift in equatorial regions hitherto unknown in the Pacific. It is much to be regretted that there are no current papers distributed over the Indian Ocean, between Java and Australia. Current papers (on chart) numbers 652 (11·2 miles per day) and 671 (19·5 miles per day) indicate a current similar to that in the Indian Ocean. The slower drift of other current papers in that sea, may, I think, be attributed to the slow exchange amongst the islands, and I fear that very many get lost amongst the islands. It is much to be desired to know which way the main currents traverse the Pacific Ocean, and this pamphlet shews a number of current papers. Many more how-

ever are wanted to see what is the direction, and speed of the currents, and might be set afloat with advantage, to gather not only the direction of the main currents but also some of the uncertain currents which have been detected.

The majority of current papers set afloat never come back, and the impression I have acquired is that one of the great, if not the greatest loss of current papers, is the want of a coating on the corks with hot pitch. The way it is done, I am told, is to make the pitch hot and dip the neck of the bottle with the cork in it.

Of the current papers of this year no less than twenty-seven have been more than a year old when received, and one of them was 2,175 days, nearly six years. It was thrown over by the R.M.S. "*Ormuz*," on September 2nd, 1895, and found August 17, 1901, it is No. 684, and was thrown over in Spencer's Gulf and found at no great distance from the starting point; how it was preserved does not appear. Two others are of special interest, first No. 702 was thrown into the sea 18° east of Falkland Islands, and landed on Stewart Island south of New Zealand, after travelling 9,850 miles in 893 days, the daily rate being 11·0 miles. The next is No. 659, which made a run of 9,950 miles at a daily rate of 7·3 miles and landed on the south-east point of South Australia. A list of six others ranging in miles travelled from 5,610 to 4,130 will be found further on.

The following list of current papers shews the number I have received each month and year, the greatest monthly average is in October with 13·8, next comes November with 10·8; and the smallest number is 5·8 in September, taking the five years as a comparison for the months. Of these, Captain Simpson contributed forty-one which I published in pamphlet No. 2; the remainder were collected in the Sydney Observatory service, and they have brought to light many most interesting and important facts In connection with the circulation of the ocean and the work of the Mercantile Marine, one fact although solitary bears in a remarkable way on the straight drift of the current papers:

Capt. S. M. Orr determined to send bottles with current papers in them fastened to floating wood, it was thrown over to the south of Australia, and was found eight months later still in the Australian Bight. When the two points were connected on the chart by a straight line it was parallel to the long lines drawn in the same sea thousands of miles long.

This list of current papers arranged in months in which the were received is interesting:—

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1896	No	obse	rvat	ions			Wor	k be	gan	8	7	11	26
1897	5	7	4	5	10	7	9	9	3	8	9	5	81
1898	4	5	6	2	8	7	5	8	4	16	7	11	83
1899	11	11	11	6	12	9	9	14	6	14	10	9	122
1900	13	14	11	12	8	10	9	7	8	17	10	7	126
1901	13	10	12	11	9	10	5	7	8	11	11	...	107
Total	46	47	44	36	51	43	37	45	29	69	54	43	545
erage	9·2	9·4	8·8	7·2	10·2	8·6	7·4	9·0	5·8	13·8	10·8	8·6	

The following letter to me should be placed on record:—

"S.S. *Sussex*, Albany, W. A., 23rd July, 1901.

"I beg to inform you that on the 12th inst., whilst en route from South Africa, this steamer passed quite close to an iron buoy floating on its side, apparently adrift in the ocean. It had a flat top with a projection as well as we could see like those on gas buoys used for marking channels. We could not see any distinctive marks whatsoever, and it looked as if it had been painted red, but owing to its being in the water so long a time, it was covered with barnacles and grass. Position of buoy worked from noon position, Lat. 34° 44′ S., Long. 68° 36′ E.

(Signed) B. HAYWARD, Master."

DERELICT IN THE SOUTHERN OCEAN.

November 30th, 1901.—The ship *Loch Broom*, on arrival at Melbourne, reported having sighted a derelict, which had evidently been destroyed by fire. The following clipping by the mail may throw some light on the subject: "A telegram from Lloyd's agent at Bahia, dated September 20, states that the Glasgow barque *Norfolk Island* was totally lost by fire at sea in Lat. 25° 5′, Long.

23 W. Part of the crew was landed there, comprising the captain, second officer, carpenter, steward, and seven sailors; the remainder of the crew has also turned up. The *Norfolk Island* was bound from Leith to Table Bay; she was a steel barque of 1,360 gross tons, and owned in Glasgow." The derelict was sighted by the *Loch Broom* on September 30 in Lat. 26° 40′ S., Long. 23° 20′ W. and, from the information supplied by our correspondent, there appears every reason to believe that it was the *Norfolk Island*.

No. of papers put overboard.*	Date when put over.	Name of Ship.	No. of these papers found.
13	October 11 to 24, 1901 ...	R.M.S. "Cuzco"... ...	0
2	January 19 to 27, 1901	S.S. "Gulf of Ancud"	0
33	June 23 to July 25, „	S.S. "Gulf of Bothnia"	0
88	Jan. 17 to Oct. 17, „	R.M.S. "Himalaya" ...	1
20	Sept. 29 to Oct. 16, „	R.M.S. "India"	4
61	March 13 to Nov. 17, „	S.S. "Indraghiri" ...	3
110	Jan. 24 to Nov. 30, „	S.S. "Manapouri" ...	3
14	October 18 to 30, „	R.M.S. "Oruba" ...	0
75	Feb. 7 to Nov. 30 „	M.M.S.S. "Pacifique" ...	0
18	August to November, „	S.S. "Macquarie" ...	0
9	May 23 to June 12, „	S.S. "Narrung"... ...	1
128	Feb. 17 to Nov. 24, „	S.S. "Persic"	2
26	Jan. 24 to Feb. 14, „	S.S. "Rotokino"... ...	0
57	May 1 to Sept. 26, „	S.S. "Salamis"	0
28	June 18 to July 15, „	S.S. "Star of N. Zealand"	0
71	Dec. 24, 1900 to Aug. 24 „	M.M.S.S. Ville de la Ciotat	3
42	September 6 to 27, „	S.S. "Star of N. Zealand"	0
795			17

* The number of current papers sent overboard as far as known, but in some cases the record of papers set afloat is incomplete.

One hundred and fifty-three papers received during the same period.

LIST OF CHARTS.

Current paper Chart No. 6A.
„ „ „ No. 6B.
„ „ „ No. 6C.

LONG DRIFTS OF CURRENT PAPERS, SELECTED FROM THE SIX PAMPHLETS PUBLISHED BY THE SYDNEY OBSERVATORY.	Number of paper in list.	Distance travelled in miles.	Rate per day in miles.
Current pamphlet, No. 1 (July 1883 to June 1894 ; 43 current papers)	2	3,300	4·0
	3	5,100	12 0
	27	3,600	9·5
	37	4,100	7·0
Current pamphlet, No. 2 (June 1894 to August 1896 ; 157 current papers)	180	5,905	9·2
	170	5,970	9·4
	169	4,779	9·3
	168	8,840	9·2
	157	9,517	9·0
	163	8,617	7·9
	164	9,585	10·3
	128	4,760	...
	147	4,081	9 0
	148	4,557	11·7
	158	6,375	8·6
	165	4,339	5·7
Current pamphlet No. 3 (August 1896 to November 1898; 167 current papers)	216	5,650	9·2
	215	4,800	7·8
	217	4,600	12·4
	218	4,890	14·2
	357	5,115	8·1
Current pamphlet No. 4 (November 1898 to November 1899; 124 current papers)	430	9,567	9·5
	452	9,025	12·2
	451	8,850	...
	385	4,100	11·2
	409	4,714	9·2
	410	4,550	8·5
	425	6,300	7 4
	466	6,550	13·3
Current pamphlet No. 5 (November to October 1900; 106 current papers)	510	3,850	7·3
	527	5,321	4·5
	561	3,785	25·4
	574	4,400	20·6
	587	3,740	18·5
Current pamphlet No. 6 (October 1900 to November 1901 ; 154 current papers)	659	9,950	7 3
	702	9,850	11 0
	680	4,665	6 0
	681	4,540	15 5
	691	4,250	15·9
	708	5,610	5 2
	726	4,130	6·0
	741	4,165	7·7

LIST OF CURRENT PAPERS THAT MADE A RAPID DAILY DRIFT,

Taken from Current Pamphlets Nos. 1 to 6 inclusive.

No. of Pamphlet.	List number of paper.	Miles per day.	Locality of Current.
1	3	12·0	South Coast
	5	11·0	East Coast
	8	16·0	East Coast
	21	31·0	Arabia
	25	11·2	North Pacific
	41	12·0	East Coast
2	56	16·8	Indian Ocean
	64	17·7	East Coast
	102	15·4	Indian Ocean
	104	14·4	India Coast
	107	18·8	South Coast
	130	18·1	Atlantic Ocean
	148	11·7	Southern Ocean
	175	18·6	Brazil
3	210	13·5	Indian Ocean
	211	21·2	South Coast
	217	12·4	Southern Ocean
	218	14·2	Indian Ocean
	222	11·7	Indian Ocean
	233	15·3	Indian Ocean
	258	16·9	Indian Ocean
	261	28·3	West Indies
	273	11·7	Arabian Sea
	323	12·5	Indian Ocean
	329	16·0	East Coast
	353	21·3	English Channel
	355	11·5	Tasman Sea
	358	14·2	South Coast
	364	19·4	Indian Ocean
	366	14·7	Indian Ocean
4	380	13·2	South Coast
	385	11·2	Southern Ocean
	388	14·0	South Coast
	392	13·3	East Coast
	406	12·7	East Coast
	418	17·8	English Channel
	431	11·5	East Coast
	433	14·2	South Pacific
	449	14·5	Indian Ocean
	450	12·9	Southern Ocean
	452	12·2	Southern Ocean
	454	12·1	South Atlantic
	456	12·7	Indian Ocean
	466	13·3	Southern Ocean
	488	12·6	East Coast
	491	18·3	West Africa
5	514	12·9	East Coast
	529	15·6	Indian Ocean
	530	16·5	Gulf of Aden
	532	21·4	Gulf of Aden
	551	19·4	North Pacific
	559	14·6	Ceylon Coast
	561	25·4	Indian Ocean
	574	20·6	Indian Ocean
	581	16·3	East Coast
	587	18·5	Indian Ocean
6	598	11·1	North of Fiji
	625	17·1	New Caledonia
	644	16·2	Gulf of Aden
	652	11·2	Oceania
	658	11·5	Coast nr. Sydney
	668	11·6	E. of N. Caledonia
	671	19·5	Gilbert Islands
	674	16·8	Phœnix Islands
	676	17·1	Coast S. of Sydney
	681	15·5	Indian Ocean
	687	18·5	Indian Ocean
	690	12·5	S.E. Coast
	691	15·9	Indian Ocean
	702	11·0	S. Indian Ocean
	711	11·3	Indian Ocean
	727	12·7	Indian Ocean
	732	22·5	Fiji
	734	17·9	Gulf of Aden
	750	11·4	Indian Ocean

Ref. No.	Date when put into the sea.	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated Distance in Miles.	Rate per Day.	Ref. No.
598	Jan. 22, 1900	R.M.S. 'Aorangi'	C. W. Hay, Commander ...	5 51 S.	174 44 E.	6 0 S.	177 45 E.	April 3-00	South Pacific	19	210	11·1	598
599	Feb. 14-00	,, ...	,, ...	7 6 ,,	173 57 ,,	7 10 ,,	177 48 ,,	May 29-00	,,	104	270	2·6	599
600	Mar. 27-00	,, ...	,, ...	6 41 ,,	173 39 ,,	7 5 ,,	157 45 ,,	Aug. 16-00	,,	142	1,380	9·7	600
601	Mar. 31-01	,, ...	,,	18 19 ,,	162 8 ,,	13 45 ,,	143 38 ,,	Sept. 13-01	,,	166	1,080	6·5	601
602	Sept. 28-99	R.M.S. 'Alameda'	— Van Otterendorp, Com.	33 58 ,,	165 33 ,,	16 44 ,,	146 3 ,,	Jan. 11-01	Tasman Sea	470	1,717	3·6	602
603	Feb. 13-01	,, 'Austral'	A. J. Coad, Commander ...	2 3 N.	83 22 ,,	10 20 N.	79 22 ,,	Aug. 13-01	Indian Ocean	181	630	3·5	603
604	Aug. 8-00	,, 'Australia'	J. Reeves, ,, ...	37 48 S.	149 40 ,,	24 40 S.	153 20 ,,	April 28-01	S.E. Coast ...	263	975	3·7	604
605	April 10-01	,, ...	,, ,, ...	37 12 ,,	139 32 ,,	37 6 ,,	139 48 ,,	April 21-01	,,	11	15	1·4	605
606	April 12-01	,, ...	,, ,, ...	35 38 ,,	132 2 ,,	35 30 ,,	138 53 ,,	June 26-01	South Coast	76	390	5·1	606
607	April 22-00	M.M.S.S. 'Australien' ...	— Vernon, ,, ...	35 38 ,,	132 3 ,,	37 56 ,,	140 32 ,,	Nov. 4-00	,,	206	490	2·4	607
608	Aug. 12-00	,, ...	,, ,, ...	35 28 ,,	132 0 ,,	37 30 ,,	140 1 ,,	Jan. 9-01	,,	150	460	3·1	608
609	Nov. 9-00	,, ...	,, ,, ...	38 26 ,,	148 6 ,,	37 48 ,,	148 35 ,,	Dec. 2-00	S.E. Coast ...	23	50	2·2	609
610	July 12-01	,, ...	,, ,, ...	37 20 ,,	139 39 ,,	38 0 ,,	140 30 ,,	Sept. 14-01	,,	64	57	0·9	610
611	Feb. 22-00	G.M.S. 'Barbarossa' ...	A. Richter, ,, ...	38 37 ,,	142 9 ,,	38 35 ,,	143 12 ,,	Nov. 4-00	,,	255	70	0·3	611
612	Oct. 31-00	R.M.S. 'Britannia'	F. H. Seymour, ,, ...	37 45 ,,	140 6 ,,	37 40 ,,	140 11 ,,	Nov. 9-00	,,	9	6	0·7	612
613	Mar. 22-99	Ship 'Commonwealth' ...	Capt. Cooper, Master ...	25 0 ,,	69 0 ,,	17 30 ,,	49 55 ,,	No date ...	Indian Ocean	...	2,580	...	613
614	Jan. 12-01	R.M.S. 'Cuzco'	B. L. Grace, Commander ...	35 37 ,,	132 37 ,,	34 55 ,,	135 45 ,,	June 17-01	South Coast	156	180	1·2	614
615	April 12-98	S.S. 'Damascus'	A. H. H. G. Douglas, R.N.R.	40 49 ,,	139 32 ,,	40 0 ,,	144 10 ,,	May 31-01	,,	1145	250	0·2	615
616	Sept. 6-98	G.M.S. 'Darmstadt' ...	M. Eichel, Commander ...	11 3 N.	63 1 ,,	2 7 ,,	41 5 ,,	Aug. 4-01	Arabian Sea	1062	1,760	1·7	616
617	Sept. 23-00	S.S. 'Eastern'	W. Ellis, ,, ...	30 6 S.	153 17 ,,	29 35 ,,	153 23 ,,	Oct. 18-00	East Coast ...	28	35	1·3	617
618	Nov. 21-00	,, ...	,, ,,	0 58 N.	125 30 ,,	2 0 N.	127 50 ,,	Jan. 5-01	Celebes Sea	45	170	3·6	618
619	Feb. 17-98	S.S. 'Gulf of Bothnia' ...	T. Ligertwood, Command.	35 40 S.	126 50 ,,	37 40 S.	140 11 ,,	Nov. 4-00	South Coast	625	750	1·2	619
620	July 27-98	,, ...	,, ,,	38 44 ,,	108 0 ,,	32 25 ,,	126 35 ,,	June 18-01	S.W. Coast ...	1053	11,25	1·1	620
621	Jan. 11-00	,, ...	,, ,,	44 7 ,,	90 11 ,,	34 56 ,,	135 43 ,,	Jan. 20-01	South. Ocean	374	2,130	5·7	621
622	Jan. 19-00	,, ...	,, ,,	35 15 ,,	123 30 ,,	32 50 ,,	137 41 ,,	April 21-01	South Coast	457	860	1·9	622
623	Feb. 24-00	S.S. 'Hauroto'	W. J. Newton, ,,	20 58 ,,	172 39 ,,	21 10 ,,	167 30 ,,	April 2-00	South Pacific	37	325	8·8	623
624	Oct. 24-00	,, ...	,, ,,	29 31 ,,	158 8 ,,	36 2 ,,	150 6 ,,	Mar. 18-01	East Coast ...	135	665	4·9	624
625	Dec. 15-00	,, ...	,, ,,	23 41 ,,	157 38 ,,	21 35 ,,	167 55 ,,	Jan. 25-01	,, ...	41	700	17·1	625
626	June 5-01	S.S. 'Hawea'	J. Abram, ,,	42 30 ,,	174 50 ,,	42 55 ,,	173 17 ,,	July 20-01	N.Z. Coast ..	45	83	1·9	626
627	April 26-01	R.M.S. 'Himalaya'	W. L. Broun, ,,	35 32 ,,	130 28 ,,	38 24 ,,	142 25 ,,	Oct. 6-01	South Coast	163	675	4·1	627
628	Dec. 28-98	Ship 'Hyderabad'	... ...	40 50 ,,	45 0 ,,	34 20 ,,	119 35 ,,	... ...	South. Ocean	...	4,090	...	628
629	July 20-00	R.M.S. 'India'	W. D. G. Worcester, R.N.R.	35 25 ,,	132 14 ,,	36 0 ,,	139 32 ,,	Nov. 15-00	South Coast	118	855	8·0	629
630	Aug. 28-00	,, ...	,, ...	2 25 N.	83 33 ,,	9 30 N.	81 15 ,,	Feb. 22-01	Indian Ocean	178	535	3·0	630
631	Sept. 3-00	,, ...	,, ...	9 41 ,,	66 27 ,,	4 12 ,,	73 28 ,,	Nov. 11-00	Arabian Sea	69	530	7·8	631

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632	Sept. 17-00	R.M.S. 'India'	W. D. G. Worcester, R.N.R.	42 12 N	4 8 E.	41 12 N.	1 35 E	Oct. 7-00	Mediterranean	20	130	6·5	632
633	Sept. 18-00	,, ...	,, ...	37 39 ,,	1 31 ,,	36 43 ,,	2 12 W.	Oct. 14-00	,, Sea	26	188	7·2	633
634	Sept. 19-00	,, ...	,, ...	36 1 ,,	6 2 W.	36 3 ,,	5 37 ,,	Oct. 5-00	Spanish Coast	16	19	1·2	634
635	Oct. 6-00	,, ...	,, ...	50 18 ,,	2 49 ,,	55 3 ,,	8 23 E.	Dec. 22-00	English Chan.	77	625	8·1	635
636	Feb. 20-00	,, ...	,, ...	3 45 S.	88 12 E.	7 14 S.	72 26 ,,	Oct. 10-00	Indian Ocean	232	1,100	4·7	636
637	Oct. 7-00	,, ...	,, ...	45 34 N	7 58 W.	44 38 N	1 13 W.	Dec. 13-00	Bay of Biscay	66	285	4·3	637
638	Nov. 7-00	,, ...	,, ...	34 41 S.	115 25 E.	34 13 S.	115 2 E.	Nov. 15-00	S.W. Coast ..	8	32	4·0	638
639	Nov. 8-00	,, ...	,, ...	35 29 ,,	122 40 ,,	34 22 ,,	119 34 ,,	Mar. 30-01	South Coast	143	200	1·5	639
640	Nov. 11-00	,, ...	,, ...	36 50 ,,	139 18 ,,	35 10 ,,	137 30 ,,	April 8-01	,,	148	170	1·1	640
641	Jan. 3-01	,, ...	,, ...	37 5 N.	18 10 ,,	37 42 N.	20 45 ,,	Mar. 10-01	Mediterranean	66	140	2·1	641
642	June 1-01	,, ...	,, ...	35 37 S.	132 22 ,,	36 0 S.	139 30 ,,	Sept. 8-01	South Coast	99	405	4·1	642
643	Jan. 10-01	,, ...	,, ...	45 23 N.	7 48 W.	43 29 N.	3 50 W.	Mar. 19-01	Bay of Biscay	68	250	3·8	643
644	Feb. 12-01	,, ...	,, ...	13 58 ,,	51 9 E.	13 30 ,,	45 0 E.	Mar. 17-01	Gulf of Aden	36	420	16·2	644
645	May 20-01	,, ...	,, ...	12 23 ,,	48 20 ,,	22 25 ,,	72 12 ,,	... ...	Arabian Sea	...	1,710	...	645
646	April 6-01	S.S. 'Indraghiri' ...	G. W. Haywood, Command	38 18 S.	144 30 ,,	38 30 S.	144 45 ,,	April 11-01	South Coast	5	15	3·0	646
647	April 5-01	,, ...	,, ,,	39 38 ,,	141 0 ,,	38 28 ,,	144 8 ,,	April 26 01	,,	21	195	9·3	647
648	April 26-01	,, ...	,, ,,	34 0 ,,	169 10 ,,	34 36 ,,	172 48 ,,	Aug. 5-01	Tasman Sea	101	200	2·0	648
649	May 2-00	Ship 'Invermark' ...	A. E. Bolderston, Master...	41 33 ,,	98 9 ,,	38 20 ,,	142 30 ,,	Jan. 13-01	South. Ocean	256	2,360	9·2	649
650	June 9-00	S.S. 'Kasuga Maru' ...	E. W. Haswell, Command.	21 59 ,,	150 50 ,,	24 40 ,,	153 16 ,,	Jan. 9-01	East Coast...	214	230	1·1	650
651	July 2-00	,, ...	,, ...	21 20 ,,	149 57 ,,	32 20 ,,	152 32 ,,	Dec. 21-00	,,	172	740	4·3	651
652	Aug. 30-00	,, ...	,, ...	3 47 N.	124 8 ,,	3 15 ,,	154 45 ,,	Mar. 11-01	Oceania ...	193	2,160	11·2	652
653	Dec. 3-00	,, ...	,, ...	8 11 S.	135 32 ,,	10 35 ,,	142 15 ,,	Feb. 9-01	South Pacific	68	280	4·1	653
654	Dec. 6-00	,, ...	,, ...	18 12 ,,	146 43 ,,	17 45 ,,	146 9 ,,	Dec. 31-00	East Coast...	25	45	1·8	654
655	Dec. 16-00	,, ...	,, ...	33 10 ,,	148 52 ,,	35 0 ,,	150 53 ,,	March 3-01	S.E. Coast ...	77	210	2·7	655
656	Dec. 28-00	,, ...	,, ...	30 14 ,,	153 15 ,,	30 57 ,,	153 6 ,,	Jan. 6-01	East Coast ...	9	50	5·6	656
657	Dec. 30-00	,, ...	,, ...	24 41 ,,	153 26 ,,	27 7 ,,	153 26 ,,	Feb. 6-01	,,	38	168	4·4	657
658	Mar. 12-01	,, ...	,, ...	29 28 ,,	153 33 ,,	33 20 ,,	151 27 ,,	April 8-01	,,	27	310	11·5	658
659	April 26-97	Barque 'Lake Erie' ...	H. Monro, Master	53 0 ,,	56 0 W.	38 15 ,,	141 0 ,,	Jan. 9-01	South. Ocean	1353	9,950	7·3	659
660	Jan. 31-00	S.S. 'Langton Grange'	W. Crichton, Commander	35 38 ,,	121 4 E.	36 18 ,,	139 43 ,,	Dec. 20-00	South Coast	323	1,050	3·3	660
661	Aug. 8-99	Barque 'Loongana'	W. T. Wawn, Master ...	23 0 ,,	154 25 ,,	22 48 ,,	150 55 ,,	May 19-01	East Coast ...	649	230	0·4	661
662	June 18-99	S.S. 'Manapouri' ...	G. Crawshaw, Commander	22 54 ,,	170 39 ,,	16 28 ,,	145 32 ,,	Mar. 10-01	South Pacific	639	1,720	2·7	662
663	Nov. 17-00	,, ...	,, ...	20 7 ,,	173 58 ,,	21 8 ,,	167 30 ,,	Mar. 5-01	,,	108	450	4·2	663
664	Jan. 15-01	,, ...	,, ...	28 25 ,,	159 59 ,,	27 40 ,,	153 30 ,,	June 2-01	East Coast...	138	400	2·9	664
665	Jan. 17-01	,, ...	,, ...	32 15 ,,	158 34 ,,	33 47 ,,	151 19 ,,	Feb. 20-01	,,	34	123	3·6	665

OCEAN CURRENTS.

Ref No.	Date when put into the sea.	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated Distance in Miles.	Rate per Day.	Ref. No.
666	March 6-01	S.S. 'Manapouri'	G. Crawshaw, Commander	32 30 S.	152 45 E.	33 2 S.	151 43 E.	Mar. 16-01	East Coast...	10	62	6·2	666
667	April 15-01	"	" ...	22 25 "	176 15 W.	19 50 "	178 5 "	June 8-01	South Pacific	54	410	7·6	667
668	April 27-01	"	" ...	21 18 "	171 56 E.	21 20 "	167 30 "	May 21-01	"	25	290	11·6	668
669	July 24-99	R M.S. 'Miowera'	F. A. Hemming, " ...	21 32 "	171 23 "	16 30 "	145 30 "	Mar. 25-00	"	244	1,770	7·3	669
670	Dec. 1-99	"	" " ...	7 42 N.	172 58 W.	6 3 "	169 45 "	July 3-00	Oceania ...	214	1,180	5·5	670
671	April 6-00	"	" " ...	3 45 "	176 34 "	1 54 "	172 58 "	May 15-00	"	39	760	19·5	671
672	June 23-00	"	" " ...	22 54 S.	158 45 E.	32 40 "	152 14 "	July 20-01	East Coast ..	412	725	1·8	672
673	Oct. 4-00	"	" " ...	40 51 N	137 48 W.	46 27 N.	124 0 W.	March 5-01	North Pacific	152	780	5·1	673
674	Mar. 25-00	" 'Moana'	M. Carey, " ...	3 17 S.	167 19 "	2 39 S.	175 52 E.	June 1-00	South Pacific	68	1,150	16·9	674
675	Sept. 5-00	" "	" " ...	20 56 "	174 51 "	17 11 "	177 12 "	.. ...	"	...	570	...	675
676	May 28-00	" 'Moravian'	A. Simpson, " ...	37 47 "	149 40 E.	33 30 "	151 27 "	June 16-00	South Coast	19	325	17·1	676
677	June 30-00	" "	" " ...	31 15 "	107 46 "	29 20 "	114 53 "	May 23-01	Indian Ocean	327	440	1·4	677
678	Nov. 10-00	" "	" " ...	36 11 "	150 36 "	33 48 "	151 19 "	Feb. 2-01	S.E. Coast ...	84	175	2·1	678
679	Dec. 12-00	S.S. 'Nemesis'	A Lusher, " ...	37 12 "	150 11 "	35 45 "	150 9 "	Mar. 30-01	"	108	100	0·9	679
680	Sept. 18-98	" 'Nineveh'	W. Allen, " ...	44 0 "	83 40 "	40 47 "	175 5 "	Nov. 3-00	South. Ocean	776	4,665	6·0	680
681	Nov. 15-00	R.M.S. 'Oceana'	C. Gadd, Commander ...	21 26 "	105 26 "	2 30 "	40 38 "	Sept. 5 01	Indian Ocean	294	4,540	15·5	681
682	Feb. 16-01	"	" " ...	35 49 "	131 12 "	37 25 "	139 53 "	July 12-01	South Coast	146	490	3·4	682
683	Sept. 13-00	" 'Omrah'	J. F. Ruthven, Command.	12 36 N.	48 11 "	15 37 N.	39 27 "	Jan. 9-01	Gulf of Aden	118	650	5·5	683
684	Sept: 2-95	" 'Ormuz'	F. M. Tuke, " ...	35 48 S	132 33 "	36 0 S.	137 14 "	Aug. 17-01	South Coast	2175	270	0·1	684
685	Mar. 20-99	" "	E. A. Veale, R.N.R. " ...	35 34 "	132 23 "	37 52 "	140 22 "	Jan. 1-00	"	287	434	1·5	6·5
686	Aug. 10-00	" "	C. Nicholson, " ...	35 39 "	132 42 "	35 5 "	136 56 "	Nov. 12-00	"	94	240	2·6	686
687	Nov. 10-00	" "	" " ...	12 30 "	96 0 "	2 35 "	40 40 "	June 8-01	Indian Ocean	210	3,890	18·5	687
688	Nov 20-00	" "	" " ...	36 56 "	139 25 "	35 35 "	138 12 "	Feb. 4-01	South Coast	77	120	1·6	688
689	Feb. 7-91	" 'Oroya'	R. Fletcher, " ...	35 29 "	132 32 "	34 54 "	137 5 "	July 14-01	"	157	265	1·7	689
690	Jan 20-00	M.M.S.S, 'Pacifique' ...	— Couret, " ...	32 20 "	152 48 "	33 2 "	151 43 "	Jan. 26-01	S.E. Coast ...	6	75	12·5	690
691	Jan. 22-00	" 'Polynesien' ...	— Chevalier, " ..	22 21 "	100 20 "	2 25 "	40 50 "	Oct. 17-00	Indian Ocean	268	4,250	15·9	691
692	May 28-00	" "	" " ...	29 27 "	154 51 "	21 23 "	149 45 "	April 18-01	East Coast ...	315	600	1·9	692
693	May 23-01	" "	" " ...	29 28 .	109 57 "	33 35 "	114 55 "	Sept. 1-01	West Coast	101	385	3·8	693
694	Feb. 26-00	'Prinz Regent Luitpold' ...	H. Walter, " ...	11 47 N	60 14 "	11 34 N	72 57 "	July 10-00	Arabian Sea	134	800	6·0	694
695	June 24-99	S.S. 'Queen Eleanor' ...	E. Ritson, " ...	31 12 S.	109 50 "	28 27 S.	114 28 "	Oct. 27-00	West Coast	490	410	0·8	695
696	May 10-01	R.M.S. 'Rome'	E. Street, " ...	35 27 "	133 10 "	38 21 "	144 26 "	July 10-00	South Coast	61	660	10·8	696
697	May 13-01	"	" " ...	33 48 "	114 50 "	34 38 "	115 50 "	Sept. 22-01	S W. Coast...	132	58	0·4	697
698	Aug. 20-01	"	" " ...	39 17 "	139 40 "	36 48 "	139 55 "	Sept 24-01	South Coast	35	137	3·9	698
699	Feb. 3-01	S.S. 'Rosetta Maru' ...	W. Tate, "	26 31 "	153 17 "	26 15 "	153 10 "	Feb. 8-01	East Coast ...	5	19	3·8	699

OCEAN CURRENTS.

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700	March 9-01	S.S. 'Rotokino'	W. J. Newton, Commander	14 11 S.	173 18 W.	17 12 S	179 3 W.	June 4-01	South Pacific	87	435	5·0	700
701	Feb. 4-00	,, 'Salamis'	A. H. H. G. Douglas, R.N.R.	47 56 ,,	79 54 E.	41 25 ,,	144 45 ,,	Feb. 1-01	South. Ocean	362	3,272	9·0	701
702	Jan. 3-99	Ship 'Silvercraig'	J. Inkster, Master	47 0 ,,	41 0 W.	46 30 ,,	168 22 ,,	June 15-01	,,	893	9,850	11·0	702
703	Oct. 20-99	M.M.S.S. 'Tanais'	M. Magnan, Commander...	28 33 ,,	158 51 E.	21 20 ,,	167 30 ,,	May 24-01	South Pacific	581	680	1·2	703
704	Aug. 20-00	S.S. 'Talune'	— Spinks, ,, ...	40 4 ,,	171 46 ,,	39 3 ,,	174 8 ,,	Nov. 9-00	,,	91	147	1·6	704
705	Oct. 1-99	,, 'Tarawera'	R. Neville, ,, ...	35 28 ,,	156 21 ,,	26 4 ,,	153 30 ,,	Jan. 14-01	East Coast .	470	675	1·4	705
706	June 3-00	,, ,, ...	,, ,, ...	34 6 ,,	169 54 ,,	21 20 ,,	167 30 ,,	May 3-01	Tasman Sea	334	790	2·4	706
707	May 25-01	,, ,, ...	,, ,, ...	34 40 ,,	154 1 ,,	33 2 ,,	151 43 ,,	July 3-01	East Coast...	39	160	4·1	707
708	May 28-98	R.M.S. 'Thermopylae' ...	W. Philip, Junr. ,, ...	47 0 ,,	63 4 ,,	40 40 ,,	175 8 ,,	May 10-01	South. Ocean	1077	5,610	5·2	708
709	June 19-98	,, 'Victoria'	W. D. G. Worcester, R.N.R.	35 8 ,,	118 27 ,,	33 25 ,,	134 30 ,,	Dec. 23-99	South Coast	553	930	1·7	709
710	April 26-00	,, ,, ...	E. Crewe, Commander ...	8 27 N.	70 40 ,,	11 30 N.	91 35 ,,	Dec. 17-00	Indian Ocean	233	1,500	6·4	710
711	Aug. 9-00	,, ,, ...	,, ,, ...	3 51 S.	88 23 ,,	0 50 S.	42 20 ,,	May 18-01	,,	282	3,180	11·3	711
712	Dec. 11-00	,, ,, ...	,, ,, ...	38 19 ,,	141 5 ,,	38 18 ,,	141 20 ,,	April 28-01	South Coast	138	14	0·1	712
713	Jan. 4-01	,, ,, ...	,, ,, ...	35 51 ,,	132 22 ,,	32 16 ,,	126 10 ,,	April 10-01	,,	96	415	4·3	713
714	Aug. 1-01	,, ,, ...	F. C. A Lyon, R.N.R., Com.	35 3 ,,	116 6 ,,	34 55 ,,	116 15 ,,	Aug. 9-01	S.W. Coast .	8	11	1·4	714
715	Aug. 5-01	,, ,, ...	,, ,,	36 25 ,,	138 44 ,,	35 45 ,,	139 17 ,,	Aug. 30-01	South Coast	25	50	2·0	715
716	Aug. 10-00	M.M.S.S. 'Ville de la Ciotat'	F. Riquier, Commander ..	33 44 ,,	113 51 ,,	33 4 ,,	115 45 ,,	Feb. 17-01	S.W Coast ..	191	130	0·7	716
717	Aug. 12-00	,, ...	,, ,, ..	35 34 ,,	131 31 ,,	33 20 ,,	134 45 ,,	June 27-01	South Coast	319	225	0·7	717
718	Aug. 21-00	,, ...	,, ,, ...	25 25 ,,	162 31 ,,	19 40 ,,	164 1 ,,	Oct. 23-00	South Pacific	63	405	6·4	718
719	Dec. 7-00	,, ...	— Fiaschi ,, ...	38 35 ,,	147 41 ,,	40 0 ,,	148 12 ,,	May 8-01	South Coast	152	80	0·5	719
720	Mar 26-01	,, ...	,, ,, ...	38 14 ,,	138 46 ,,	38 37 ,,	142 51 ,,	April 23-01	,,	28	220	7·9	720
721	Aug. 3-99	S.S. 'Waroonga'	... ...	34 13 ,,	114 48 ,,	34 20 ,,	119 37 ,,	Jan. 11-00	S.W. Coast...	161	300	1·9	721
722	Jan. 2-99	R.M.S. 'Warrimoo' ...	C. W. Hay, ,, ..	7 4 ,,	172 20 ,,	7 53 ,,	178 20 ,,	March 5-00	South Pacific	427	414	1·0	722
723	July 12-99	,, ...	,, ,, ...	1 14 ,,	171 7 W.	6 0 ,,	177 45 ,,	Jan. 20-00	,,	192	870	4·5	723
724	Oct. 11-00	,, ...	,, ,, ...	18 13 ,,	162 34 E.	29 27 ,,	153 32 ,	Feb. 24-01	,,	136	1,030	7·6	724
725	June 21-01	S.S. 'Willyama'	J. Goulding, ,, ...	38 11 ,,	138 37 ,,	38 20 ,,	141 27 ,,	Aug. 1-01	South Coast	41	156	3·8	725

OCEAN CURRENTS.

The following Papers have been received since the precceding was arranged.

Ref. No.	Date when put into the sea.	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated Distance in Miles.	Rate per Day.	Ref. No
726	Dec. 14-99	S.S. 'Afric'	— Alford, Commander	32 49 S.	29 0 E.	31 10 S.	51 0 W.	Oct. 30-01	S. Atlantic	685	4,130	6·0	726
727	Sept. 12-01	R.M.S. 'Arcadia'	A. Laggin, ,,	9 13 N.	66 43 ,,	4 10 N.	73 28 E.	Oct. 26-01	Indian Ocean	44	560	12·7	727
728	Nov. 25-00	,, 'Australia'	J. Reeves, ,,	35 11 S.	137 56 ,,	34 28 S.	138 15 ,,	Nov. 25-01	G. Aust. Bight	365	215	0·6	728
729	July 20-01	M.M.S.S. 'Australien'	— Verron, ,,	30 8 ,,	113 22 ,,	32 55 ,,	122 56 ,,	Nov. 26-01	S.W. Coast	129	810	6·3	729
730	Aug. 2-96	S.S. 'Gulf of Bothnia'	T. W. G. Ligertwood, Com.	39 36 ,,	125 0 ,,	32 15 ,,	126 50 ,,	Nov. 30-01	South Coast	1945	420	0·2	730
731	May 4-01	,, 'Gulf of Venice'	— Cook, Commander	36 51 ,,	130 30 ,,	38 38 ,,	145 30 ,,	Nov. 17-01	,,	197	830	4·2	731
732	Oct. 14-00	,, 'Hauroto'	W. J. Newton, ,,	16 30 ,,	178 44 W.	17 0 ,,	178 47 ,,	Oct. 26-00	South Pacific	12	270	22·5	732
733	Oct. 7-01	R.M.S. 'India'	W. D. G. Worcester, R.N.R.	28 50 ,,	112 14 E.	28 48 ,,	113 46 ,,	Oct. 30-01	West Coast	23	96	4·2	733
734	Sept. 23-01	,,	,,	12 27 N.	47 52 ,,	12 43 N.	43 25 ,,	Oct. 10-01	Gulf of Aden	17	305	17·9	734
735	Oct. 13-01	,,	,,	36 38 S.	142 6 ,,	38 41 S.	145 52 ,,	Nov. 30-01	South Coast	48	208	4·3	735
736	Sept. 28-01	,,	,,	7 13 N.	79 2 ,,	7 56 N.	79 45 ,,	Oct. 3-01	Indian Ocean	5	53	10·6	736
737	Dec 8-00	,,	,,	35 30 S.	125 4 ,,	37 15 S.	139 50 ,,	Oct. 18-01	South Coast	314	880	2·8	737
738	Nov. 21-00	S.S. 'Kadina'	— Rose, Commander	36 26 ,,	138 46 ,,	34 10 ,,	138 10 ,,	Nov. 7-01	,,	351	130	0·4	738
739	June 15-99	R.M.S. 'Miowera'	F. A. Hemming, Command	5 0 ,,	173 13 W	8 35 ,,	159 55 ,,	Jan 15-01	South Pacific	579	1,840	3·2	739
740	April 5-01	S.S. 'Moravian'	A. Simpson, ,,	35 32 ,,	128 36 E.	36 22 ,,	139 44 ,,	Nov. 6-01	South Coast	215	900	4·2	740
741	Dec. 18-99	,,	,, ,,	46 49 ,,	92 22 ,,	40 17 ,,	175 12 ,,	June 15-01	South. Ocean	544	4,165	7·7	741
742	June 11-01	S.S. 'Narrung'	A. W. Bond, R.N.R. ,,	36 4 ,,	133 35 ,,	37 54 ,,	140 23 ,,	Oct. 23-01	South Coast	135	408	3·0	742
743	Feb. 15-01	R.M.S. 'Oceana'	C. Gadd, ,,	35 33 ,,	123 55 ,,	37 10 ,,	139 45 ,,	Oct. 28-01	,,	255	900	3·5	743
744	Aug. 1-01	S.S. 'Persic'	J. Seally, ,,	38 20 ,,	140 10 ,,	38 58 ,,	146 16 ,,	Nov. 31-01	,,	122	335	2·7	744
745	Aug. 23-01	,,	,, ,,	34 15 ,,	25 27 ,,	34 12 ,,	24 47 ,,	Sept. 21-01	Cape Colony	29	40	1·4	745
746	Sept. 7-01	S.S. 'Rockton'	M. M. Osborne, ,,	22 37 ,,	151 5 ,,	23 32 ,,	151 15 ,,	Nov. 24-01	East Coast	78	65	0·8	746
747	Sept. 16-01	R.M.S. 'Rome'	E. Street, ,,	33 0 ,,	114 55 ,,	32 10 ,,	115 45 ,,	Oct. 27-01	West Coast	41	66	1·6	747
748	Sept. 11-01	,,	,, ,,	37 33 ,,	139 53 ,,	37 55 ,,	140 36 ,,	Oct. 27-01	South Coast	46	53	1·2	748
749	Oct. 13-96	R.M.S. 'Valetta'	G. W. Atkinson, ,,	30 8 ,,	109 42 ,,	20 30 ,,	57 35 ,,	Oct. 25-01	Indian Ocean	1837	3,400	1·9	749
750	Jan. 8-01	M.M.S.S. 'Ville de la Ciotat'	— Fiaschi, ,,	8 40 ,,	90 48 ,,	2 30 ,,	40 35 ,,	Nov. 9-01	,,	305	3,480	11·4	750
751	July 29-01	,,	,, ,,	30 48 ,,	155 56 ,,	28 32 ,,	153 33 ,,	Nov. 25-01	East Coast	119	160	1·3	751

On the OCCURRENCE of a VARIETY of TINGUAITE at KOSCIUSKO, N. S. WALES.

By Prof. David, B.A., F.G.S., F.R.S., F. B. Guthrie, F.I.C., F.C.S., and W. G. Woolnough, B.Sc., F.G.S.

[With Plates I., II.]

[*Read before the Royal Society of N. S. Wales, June 5, 1901.*]

CONTENTS.

I. *Introduction.*—The rock described in this paper was discovered during a visit of two of the authors (Messrs. David and Guthrie) in company with Mr. Richard Helms, to the Kosciusko Plateau last February. Eruptive rocks, in which the felspathoid mineral nepheline replaces felspar, are somewhat rare in their distribution, and all the more interesting on that account. In England for example, nepheline rock of the nature of phonolite is known to occur only at the Wolf Rock, S.E. of the Land's End, Cornwall. The Wolf Rock is a Nosean Phonolite.[1]

[1] S. Allport, Geol. Mag. VIII., 1871, 247, and I., 1874, 462; also F.Z., Mikrosk. Besch. 1873, 397. "The Wolf Rock lies about nine miles S.E. of the Land's End, and is covered by the sea at high water. At low water spring tide it measures only 175 feet by 150 feet, and stands 17 feet above the sea. At high water it is two feet below the level of the sea. It consists of microporphyritic crystals of sanidine and nosean; and the groundmass which is holocrystalline consists of sanidine nepheline and a few of nosean and ægirine." British Petrography, with special reference to the igneous rocks, by J. J. Harris Teall, M.A., F.G.S., p. 367.

In Scotland a nepheline-bearing rock, described as a trachytoid phonolite, occurs at Traprain Law in the Garlton Hills.[1] This phonolite, which occurs in the form of a neck is remarkable for its high geological antiquity, being of Carboniferous Age. Borolanite (a rock formed of soda-orthoclase, a little plagioclase, melanite, biotite, a little pyroxene, nepheline as elæolite, apatite and a very little magnetite, with probably sodalite), occurs as intrusive dykes or sheets in older Palæozoic rocks near Lake Borolan, Elphin and Achiltibuie in Scotland.[2]

In France a number of interesting phonolite 'necks,' (over 100 in number) have been described in the neighbourhood of Velay, Cantal and Mount Dore, Central France. Nepheline is present only in some varieties, its place being taken mostly by nosean and haüyne. In some cases the felspars consist of kernels of anorthoclase, coated with sanidine.

In Saxony phonolites of the trachytoid type have been described from Obersdorf near Zittau, while numerous nephelinoid phonolites have been described from various parts of Bohemia, such as Teplitz, Schlossberg, etc.,[4] as well as from the Rhön region.

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[1] "It is essentially formed of a mass of little sanidine prisms, in which lie ragged crystals of bright green soda-augite. There are also present colourless patches which contain little crystals of nepheline with zeolitic decomposition products."

[2] Trans. R. Soc., Edinburgh, XXXVII., Nr. 11, 1892.

[3] Von Lasaulx, Phonolith vom Mont Dore N. Jahrb. f. Min. 1872, p. 351. Michel Lévy, Phonolithes des Mont Dore, Bull. Soc. Géol. (3) XVIII., 1890, 795 – 821. Michel Lévy, Phonolithes vom Cantal, Comptes Rendus XCVIII. 1884, Nr. 22. Fouqué et Lévy, Phonolithes des Cantal, Minéralog. Micrographique, 1879. Termier, Phonolithes des Velay, Comptes Rendus CX., 1820, 730.

[4] The literature is too extensive to quote in detail. The following may be mentioned:—Möhl, Nova Acta Leop. Carol. Acad. XXXVI., Nr. 4, 1873, and N. Jahrb. f. Min. 1874, 38. Boricky, Sitzgsbr. böhm. Ges. Wissensch. 19, April 1891, and Petrog. Stud. an den Ph.-Gesteinen Böhmens Archiv. d. Naturwiss. Landesdurchforschung von Böhmen III. Bd., 2 Abth. 1 Prag. 1874. G. vom Rath, Phonolith von Zittau, Z. Geol Ges. VIII., 1856, 291. Sandberger, N. Jahrb. f. Min. 1888, II., 248; and Exc. N. Jahrb f. Min. 1881, II, 211. F. Zirkel., Mikr. Besch. 394, 396, and Z. Geol. Ges. XI., 1859, 534. G. vom Rath, Correspondenz-Blatt naturh. Vereins, 1866, 46; K. Vogelsang, Z. Geol. Ges. XLII., 1890, 47, etc. For the above references as well as for many others in this paper, the authors are indebted to the great work of Ferdinand von Zirkel, "Mikroscopische Beschaffenheit der Mineralien und Gesteine."

Rosenbusch has described, in his magnificent work,[1] a variety of nepheline rock, which he refers to the basic group, from the Katzenbuckel, a dome shaped hill in the Odenwald, Baden. He terms this rock phonolitic nephelinite. In many respects it very closely resembles the Kosciusko nepheline rock, but the Katzenbuckel rock contains some olivine together with abundant häuyne, whereas these two minerals are wanting in the Kosciusko rock.

Professor Brögger has described nepheline rocks which though not definitely phonolites, are nevertheless as regards chemica composition, so closely allied to the Kosciusko rock, that they may be quoted here for comparison.

The rock described by him under the section of laurdalite from Lunde, Lougenthal, in the Christiania district is shown by its chemical composition to be not far removed from the nepheline rock of Kosciusko. A comparison however, of its chemical composition with that of the Kosciusko rock shows that the laurdalite is richer in lime than that of Kosciusko and correspondingly poorer in soda. Mineralogically it differs from the Kosciusko rock chiefly in having phenocrysts developed of potash felspar belonging to the varieties sanidine and orthoclase. In other respects, however, its minerals agree very closely with those developed in the Kosciusko rock.

The same author has described under the term nepheline-porphyry, also from the Lougenthal, a rock both chemically and mineralogically intimately related to that of Kosciusko. This nepheline-porphyry is richer in soda than the laurdalite, containing 11·36% of soda as compared with 8·18% in the latter. This alumina per centage in nepheline-porphyry is higher than that in the Kosciusko nepheline rock, and mineralogically it differs from the Kosciusko rock chiefly in having potash felspar developed as phenocrysts. The rock termed tinguaite, described by him from Hedrum, lithologically very closely resembles the Kosciusko rock.

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[1] Microscopische Physiographie der Mineralien und Gesteine, dritte Auflage, Vol. II., p. 1260.

At S. Antão, however, in the Cape Verde Islands, Doelter[1] has described a phonolitic nephelinite which in mineral constitution appears to approximate closely to the Kosciusko rock. Rosenbusch (p. 1260) describes this rock as being conspicuously green in colour, the nepheline being present in sharply idiomorphic crystals, in which two generations can be distinctly recognised, whereas the sanidine occurs sparingly or more abundantly in small laths ("Leistchen"), the structure of the rock being evidently porphyritic.

Sauer[2] has described a nepheline—haüyne phonolite with pleochroic augite, a little hornblende and plagioclase from the Canary Islands.

Doelter[3] has also described a trachytoid phonolite from the volcano Mount Ferru, in Sardinia, varying from a rock poor in nepheline to one in which the nepheline is in excess of the sanidine. Haüyne occurs sparingly.

Deecke[4] has described phonolite dykes in the tuff of the crater walls of Vico in the Ciminian Hills of Italy. Nepheline, sanidine, augite, haüyne, plagioclase and titanite are present.

Professor J. W. Gregory, has described[5] nepheline-syenites, phonolite dykes and kenyte lavas from Mt. Kenia. The last mentioned consists of a glassy matrix very rich in soda, with granules of ægirine, felspar microliths and phenocrysts of anorthoclase.[6]

Rosiwal has described a nephelinite from the Maerú Mountains (Meru-Berg) from S. E. Africa.[7] This contains some brown

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[1] Doelter (C), Die Vulkane der Capverden und ihre Produkte. Gratz, 1882.

[2] Sauer. Phonolithische Gest. Der Canarischen Inseln, Inaug.—Diss. Halle 1876—Ztschr. f. d. ges. Naturw., XLVII., 1876.

[3] Doelter, Phonolith von Sardinien, Denkschr. Wiener Akad. XXXIX, 1878, 59.

[4] Phonolith von Vico, Italien. N. Jahr. f. Min. Beilageb. VI., 1889, 239.

[5] Gregory (J. W.), Q.J.G.S., Vol. LVI., 1900, pp. 205 – 202 and pls. X., xi. and xii. *pars* "The Geology of Mt. Kenia," and Q.J.G.S., Vol. LVI, 1900, pp. 223 – 229 and pl. xii. *pars*. "The Nepheline-syenite and Camptonitic dykes intrusive in the Coast Series of British East Africa."

[6] See also Min. Mag. Vol. XII.. July 1900, pp. 255 – 273. "Ægirine and Riebeckite anorthoclase rocks related to the Grorudite-Tinguaite Series, from the neighbourhood of Adowa and Axum, Abyssinia," by G. T. Prior.

[7] Rosiwal, Denkschr. Wien Akad. LVIII., 1891, 487.

akmite. He has also described phonolite from Mt. Kenia and its neighbourhood, containing anorthoclase, nepheline, augite, ægirine and acmite.

G. Rose,[1] Rosenbusch, and van Werveke have described nepheline bearing rocks from Messid Gharian, from the great volcanic cone of Tekut, and from Mantrus, all situated in Tripoli. These are mostly dark grey phonolites with idiomorphic nepheline laths of sanidine and pyroxene; sodalite hornblende and haüyne with titanite, magnetite and apatite are present in some varieties.

J. Roth, has described a sanidine-augite-haüyne phonolite with a little nepheline from Kordofan.[2]

Vélain has deseribed a nepheline phonolite from the peninsula of Aden,[3] occurring in sheets, flows, and dykes. Nepheline, sanidine, plagioclase, green augite and magnetite compose it. Vélain considers these phonolites to be newer than the rhyolites and trachytes of the same neighbourhood.

Steinecke[4] has described a phonolite rich in biotite but poor in nepheline, from between Choi and Kosehkserai Marand in Persia.

In North America nepheline rocks of the nature of phonolites have been described from Dakota and Colorado.[5]

In South Dakota they form conspicuous conical hills, such as Mato Tepee, the core of a laccolith.[6]

A curious type of phonolite rich in hornblende, and terme apachite has been described by Osann, from the Apache Mountains.[7]

[1] G. Rose, Z. Geol. Ges. III., 1851, 105.

[2] J. Roth, Allg. u. Chem. Geologie II., 262.

[3] Vélain, Descript. Géol. de la presq 'île d' Aden, 1878, 35.

[4] Steinecke, Phonolith aus Persien, Z. f. Naturw. 4, Folge, VI., 1887, 45.

[5] Whitman Cross, Proc. Colorado Scientifi. Soc., 1887, 167.

[6] Some of the principal phonolite localities in U. S. America, are Big Bull Mountain; Mitre Peak; Straub Mountain; Rhyolite Mountain; Florissant and Manitou; Bull Cliff; Washington Shaft, Victor.

[7] Osann, Phonolite (Apachite) of the Apache Mountains, U.S.A.—Tschermak's Min. u. petr. Mitt., 1896, Vol. xv., p. 394. Rosenbush, Microscopische Physiographie der Mineralien und Gesteine, dritte Auflage 1896, p. 823.

Dr. F. Adams[1] and Mr. A. P. Coleman[2] have described a corundiferous nepheline syenite from Eastern Ontario. This remarkable rock is described as having a schistose structure, "so that at first sight it would be called gneiss. The darker layers contain much biotite and the lighter nepheline and plagioclase. Numbers of small crystals of corundum stand out on the weathered surfaces. Mr. Frank D. Adams has referred[3] to a rock formed of white felspar and orange-red grains of elæolite, described by Sir William Logan from Old Pic Point and Island, Lake Superior. It is thought to be probably related to the remarkable analcite rock called heronite, described by A. P. Coleman from Heron Bay, Lake Superior.[4] This rock, heronite, is considered to have the following mineral constitution :—

Analcite	47·00
Orthoclase	28·24
Labradorite	13 00
Ægyrite	4·04
Limonite	3·59
Calcite	1·96
	97·83

As regards the occurrence of nepheline rocks in the Southern Hemisphere, phonolites containing sanidine, nepheline, haüyne and hornblende, have been described from Fernando Noronha, off Cape S. Roche, Brazil;[5] and Renard[6] has described a volcanic

[1] Geol. Sur. Canada, 1892-3, Pt. J, p. 5; and also Amer. Journ. Sci., Vol. XLVIII., July 1894, pp. 10 - 18.

[2] Jour. of Geol., July - August 1899, Vol. VII., No. 5, pp. 437 - 444.

[3] Jour. of Geol., Vol. VIII., No. 4, May - June 1900, pp. 322 - 325, "On the probable occurrence of a large area of nepheline-bearing rocks on the north-east coast of Lake Superior.

[4] Jour. of Geology, Vol. VII., No. 5, July - August, 1899, p. 435.

[5] Gümbel, Phonolith von Fernando do Noronha, Brazilien, Min u. petr. Mitth. II., 1880, 188. Renard, Rep. on the petrology of Oceanic Islands, 1889, 33. Branner and Williams, Amer. Journ. of Sci., XXXVII., 1889, 145, 168.

[6] Renard, Phonolithe de l' isle Nightingale (Tristan da Cunha), Bull. Acad. Royale de Belg. (3) XIII., 1887, 3. Renard, Report on the petrology of oceanic islands, 1889, 89.

conglomerate of considerable extent at Nightingale Island. The cement of this conglomerate is formed of phonolitic material. Nepheline is stated to occur in grains and crystals besides brown microlites of augite and sanidine etc.

In Brazil, Prof. O. A. Derby,[1] has described a nepheline-bearing rock from Serra de Tinguá. This, however, is perhaps more referable to the elæolite-syenite-porphyries, leucite-elæolite-syenite-porphyries or tinguaites than to the phonolites. Besides elæolite it contains abundant pseudomorphs in analcime after leucite. It was originally considered to be of Palæozoic Age, but Hussak[2] has shown that it intrudes Post-Carboniferous, perhaps Triassic, sandstones.

Kerguelen.—Phonolite has been described[3] at the above island at Greenland Harbour. It is stated to be a greenish-white rock forming cylindrical and columnar masses which rise above the general level of the surrounding sheets of augitic basalt. Much soda and sulphuric acid are present.[4] From the fact that angular enclosures of the phonolite are met with in the basalt, (whereas no basalt enclosures have been observed in the phonolite), and from the fact that the basalts which are typically porphyritic become less coarsely crystalline as they approach the dome-shaped masses of phonolite, it is argued that the Kerguelen phonolites are probably somewhat older than the basalts. Professor Roth[3] and Renard[5] have also described phonolite from Kerguelen.

Mr. Evelyn G. Hogg, M.A.,[6] has also described phonolites from Kerguelen, and the adjacent Howe Island. At the latter locality the minerals present in the phonolite are sanidine, augite, hornblende and nepheline. An analysis of this rock for comparison

[1] O. A. Derby, Q.J.G.S., XLIII., 1887, 457; XLVII., 1891, 251.
[2] Hussak, N. Jahrb. f. Min., 1890, I., 166; 1892, II., 146.
[3] Report Scientific Results, Voyage H.M.S. Challenger, Narrative, Vol. I., First Part, pp. 348 - 351, and p. 374. [3] *Op. cit.*, p. 350.
[4] Roth, (Prof. J.) Ueber die Gesteine von Kergueland, Monatsber. d. K. preuss. Akad. d. Wiss. Berlin, 1875, pp. 723 - 735.
[5] Bull. Musée roy. de Belge IV., 1886, 223, and Rep. on petrology of Oceanic Islands, 1889, 133.
[6] Hogg, (E. G.) Proc. Roy. Soc. Victoria, Feb. 1899, Vol. XI., (New Series) Pt. 2, pp. 209 - 218.

with that of Kosciusko is quoted by us later on from Mr. Hogg's paper. From "Cat's Ears" on the main island, Mr. Hogg has described[1] a hornblende phonolite, (not unlike apachite, *authors*) containing sanidine, hornblende, nepheline, augite, apatite and a little sphene.

In the presence of hornblende some of these phonolites approach the apachite (Osann) of the Apache Mountains, and in the presence of olivine the phonolitic nephelenite, (bordering on the nepheline-basalts) of the Katzenbuckel in the Odenwald, Baden. In their low silica percentage, 51·15 – 52·30 they resemble the Kosciusko tinguaite, as will presently appear.

New Zealand.—The late Professor Ulrich of Dunedin, New Zealand has described[2] a very interesting group of phonolites from the neighbourhood of Dunedin at Portobello, and also at Pine Hill and Parakanui Cliffs, the first locality twelve miles east of Dunedin, and the second close to the town, and the third eighteen miles north of it. *Structurally*, Professor Ulrich differentiates them into (1) a coarsely porphyritic rock, and (2) a dense compact rock; and *mineralogically* into (*a*) nephelinitoid phonolites, and (*b*) trachytoid phonolites. Through accession of plagioclase, and either absence or presence of olivine, varieties of this rock graduate respectively towards tephrite on the one hand and basanite (Rosenbusch) on the other.

A. Wichmann[3] has described a nepheline rock under the name foyaite from Viti Levu, Fiji. This was collected by Kleinschmidt from Muanivatu and Koro Yalewa. This rock consists of orthoclase, a little plagioclase, fresh nepheline largely converted into zeolites, augite, apatite, biotite, magnetite, titanite, and titaniferous iron.

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[1] *Op. cit.*, p. 212.

[2] On the occurrence of nepheline-bearing rocks in New Zealand, by Professor George H. F. Ulrich, F.G.S., Director of the School of Mines, Dunedin.—Austr. Ass. Adv. Sci., Vol. III., pp. 127 – 150, pl. V.

[3] Tschermak's Min. u. petr. Mitth. V., 1882, 14.

W. H. Twelvetrees[1] and W. F. Petterd have described an exceedingly interesting series of nepheline, anorthoclase, nosean ægirine rocks in the neighbourhood of Port Cygnet, Tasmania. Melanite garnet and fluorite are present in some varieties: in some cases sanidine takes the place of anorthoclase. Messrs. Twelvetrees and Petterd class these as sölvsbergites nosean trachytes, and tinguaite porphyries.

As regards the occurrence of nepheline in Australia, it has hitherto been described only as an accessory mineral. Professor Ulrich has recorded[2] it in an "older basalt" (Eocene ?) at Phillip Island, Bass' Strait, Victoria. Analcime and natrolite occur in abundance as zeolites in this lava. F. M. Krause[3] also records nepheline from Victoria, at Western Port.

Recently Prof. J. W. Gregory[4] has described an interesting series of sölvsbergites and trachy-phonolites containing anorthoclase, nosean, ægirine, riebeckite, and in some cases cossyrite, from Mt. Macedon, Victoria.

In Queensland, Mr. Dunstan of the Geological Survey has referred[5] to a basalt rich in nepheline, at Mt. Beardmore, Dawson River, west, He states that this rock "occurs as an isolated peak surrounded by old sedimentary altered rocks and by tableland sandstones. The rock is fine grained and contains nepheline, augite, olivine, magnetite, etc.: no felspar present." He adds that it looks fresh.

In New South Wales, Prof. Liversidge[6] records the occurrence of nepheline in amygdaloidal porphyry at "The Pinnacles," Co., Forbes; Dowagarang and the Old Man Canobolas, near Wellington

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[1] Trans. Aust. Inst. Mining Engineers, 1898, Vol. v., p. 108, and also Papers and Proc. 1898-99, Roy. Soc. Tasmania, pp. 3 – 26, figs. 1 - 8.

[2] Quoted by R. M. Johnston, Geology of Tasmania, 1888, p. 249.

[3] "An Introduction to the Study of Mineralogy for Australian readers," F. M. Krause, 1896, p. 205.

[4] Proc. Roy. Soc., Victoria, Vol. XIV., (New Series) Pt. ii., pp. 185 – 217, Pls. xi. - xvii.

[5] Parliamentary Paper, No. C A. 9, 1901, Brisbane—Rep. Geol. Dawson and Mackenzie Rivers, 1901, p. 28. Preliminary Note.

[6] Minerals of New South Wales—A. Liversidge, M.A., F.R.S., 1888, p, 185.

(Orange ?) Co., Wellington. These spots were probably observed by the late Rev. W. B. Clarke.

Mr. G. W. Card, Assoc. R.S.M., F.G.S., Mineralogist to the Geological Survey of New South Wales, has informed us that he has lately observed nepheline in basalt from the following localities in New South Wales:—(1) at "The Peaks," Burragorang, where the lava occurs as a thin capping at the top of the mountain; (2) at Glen Alice, Capertertee; and (3) at Sapling Flat Creek, Capertee.

Mr. G. W. Card has also identified nepheline in large quantities in a rock just discovered by Mr. J. E. Carne, F.G.S., of the Geological Survey of New South Wales. The locality of the discovery is Portion 34 in the Parish of Barigan, about fourteen miles from the railway station Lue, on the Wallerawang to Mudgee Line, in N. S. Wales. In hand specimens the fine grained type of the Barigan rock is strikingly like that of Kosciusko. Mr. Card very kindly placed thin slices of this rock at our disposal, so that we might institute a comparison between it and that of Kosciusko. Since this, however, fresh discoveries on a much larger scale of highly interesting nepheline rocks, which Mr. Card considers allied to tinguaites, have been made in the same district by Mr. J. E. Carne.[1] Mr. Carne states that there are several mountains of nepheline rock in this locality over 1,000 feet high, from base to summit, and intrusive into the Permo-Carboniferous and Triassic rocks. Under these circumstances as the Barigan rocks will merit a special memoir, in all probability, it would be premature for us to attempt a description of them, except very briefly.

On comparing the sections of the fine grained variety of rock from Barigan with that of Kosciusko, one is struck at once with the absence from the former of inclusions of other rocks, the Kosciusko rock being remarkable for the amount of mineral matter, especially felspar, which it has borrowed from the surrounding gneissic granite. The Barigan rock does not exhibit under the microscope as numerous sharply defined sections of

[1] Card, G. W.—Records Geol. Survey, N. S. Wales, Vol. VII., pt. 2.

nepheline as does the Kosciusko rock. The Barigan rock does not exhibit flow structure among its felspar microlites, whereas flow structure is well seen in the Kosciusko rock. The Barigan rock moreover has numerous clear streaks, of the nature perhaps of segregation lines, not seen in the Kosciusko rock. A subsequent examination of the Barigan area by Mr. Carne and Prof. David, shows that these lines are related to directions of pressure in the tinguaitic laccolites, the rock having a banded almost gneissic appearance the bands being approximately concentric to the general surface of the laccolites.

The Barigan rock is essentially composed of nepheline and ægirine, with numerous, irregularly distributed microlites of felspar and probably a little sodalite. Further information relating to the petrological character and mode of occurrence of this highly interesting rock from Barigan and the associated tinguaites will be published shortly by the Geological Survey of New South Wales.

II. *Occurrence at Mount Kosciusko.*—The tinguaite of Kosciusko occurs in the form of a dyke traversing granite. The dyke is about seven feet wide, is vertical or nearly so, as far as can be seen in the small section in the bank of the creek, and strikes in a direction E. 5° N. and W. 5° S. The height above sea-level is about 5,600 feet. The spot where the dyke crosses the creek [which flows from Lake Merewether (Blue Lake), and Hedley Tarn through Evidence Valley (Helms) to the Snowy River] bears about E. 47° N. from the Kosciusko Observatory, and is about four miles and thirty-nine chains distant. The spot is about a quarter of a mile up Evidence Valley Creek from its junction with the Snowy River.[1]

The rock on either side of the dyke is a slightly gneissic granite. The granite extends in a westerly direction from Evidence Valley, for about one mile, when it is replaced by a belt of phyllite and fine quartzite. This belt is from about a quarter of a mile up to

[1] See *Plate* 2, for geological plan showing occurrence of dyke. See also Proc. Linn. Soc., N. S. Wales, New Series, 1901, Pt. 1, Pl. iii., and pp. 30-31.

over a mile in width; and beyond it the granite extends to a considerable distance further in a westerly direction. The eastern line of junction between the granite and the phyllite trends N. 15° E. and S. 15° W., while the western junction line is nearly meridional, so that there does not appear to be any relation between the strike of the tinguaite dyke and the junction line of the granite and phyllite. The same remark applies to the junction line of the granite with the radiolarian and graptolitic slates and cherts at twenty-nine miles in a direction E. 25° N. from Kosciusko. The folia of the granite strike N. 20° E. to N.N.E., and their prevalent dip is to E.S.E. at about 75°. The granite is strongly intrusive into both phyllites and radiolarian rocks. The age of the phyllites is unknown; but that of the latter is Lower Silurian (Ordovician). The tinguaite is strongly intrusive into the gneissic granite, and contains a large amount of included crystals of felspar, with a few of quartz and mica, derived from the granite.

An examination of the gneissic granite shows that it has been intruded by at least two distinct dyke rocks, other than the nephelinite, as well as by veins and irregular masses of a whitish euritic granite. The last mentioned is probably not much younger than the gneissic granite, as it has partaken of its foliation. The two dyke rocks referred to are respectively a pyroxene amphibolite, and an olivine basalt.

The nearest basalt dyke to the tinguaite, as far as we were able to observe, is one seen by us on the west side of Lake Merewether (the Blue Lake). It is about two feet wide and strikes in a direction from W.N.W. to W. 30° N. A much larger basalt dyke is developed on the Main Dividing Ridge to the west of Garrard's Tarn (Harnett's Lake, or Club Lake). This dyke is several yards in width and is perhaps a continuation of the dyke next to be described, viz., that at Russell's Tarn near Mount Townsend (Müller's Peak). This dyke is forty yards wide, is strongly laminated and strikes in an E.N.E. direction, whereas the laminæ trend N.N.E. and S.S.W. This dyke is rendered

porphyritic by augite and olivine, and contains numerous enclosures of granite an inch or more in diameter. A further description of one of the local basalts is given later in this paper.

There is thus nothing in these basalt dykes, except their fresh state of preservation, strong intrusion into the granite and approximate parallelism of strike (with that of the tinguaite) which connects them with the last mentioned rock. It is, however, possible that the dykes may be complementary to one another.

The tinguaite of Kosciusko is brownish-grey in colour with a faint tinge of green, and in this respect differs from the "conspicuously green" phonolitic nephelinite of S. Antão. The Kosciusko rock has not the sonorous ring of some phonolites. It breaks readily under the hammer with an uneven to sub-conchoidal fracture, and has a somewhat greasy lustre. Macroscopic whitish-grey to pale reddish-grey crystals of nepheline can be seen on freshly fractured surfaces, giving the rock a somewhat pseudo-porphyritic appearance, though probably the rock is not really porphyritic in the strict sense of that term as used by Rosenbusch.

III. *Microscopic Character.*—The specimens in the following description were taken from the following portions of the dyke:— No. 1 from northern side of dyke within six inches of its plane of junction with the granite. No. 3, from the centre of the dyke. No. 4, from the southern side of the dyke within six inches of its plane of junction with the granite.

No. 1. In thin section the rock is seen to possess a hyalopilitic texture. A considerable amount of residual glass is present. It is colourless, but contains fairly numerous dusty crystallites. A very marked flow structure is apparent. None of the minerals show definite evidence of occurring in more than one generation, though the rock is rendered pseudo-porphyritic by occasional largely developed nephelines. The reasons for considering these large phenocrysts of the same generation as the small individuals of the base are:—(*a*) there is a perfect gradation from the largest crystals to those of sub-microscopic dimensions; (*b*) there is no distinction

in microstructure between the large and the small crystals; (*c*) there is a total absence of any trace of resorption; (*d*) the larger nephelines are surrounded by ægirines more densely packed than in other parts of the base, pointing to the fact that these nephelines have grown in size in the place where they are now found, pushing the ægirines aside in the process. If we accept Rosenbusch's definition for "porphyritic structure," that term cannot therefore be applied to the rock under consideration.

The most obvious and important mineral constituent is nepheline. This occurs as occasional, fairly large, idiomorphic crystals in stumpy hexagonal prisms with basal planes. These vary in size up to 3 mm. in length, the breadth being about the same. Mr. G. W. Card states that he has observed well developed pyramid faces modifying the rectangles, but such faces appear to be exceptional. The mineral is clear and colourless and its refractive index and double refraction are characteristic. In places, grey, yellow and brownish decomposition products are abundant. The large nepheline crystals have a marked zonal structure, the central zones possess a higher refractive index than those near the periphery, as proved by testing them by Becke's method.

In the small crystals a similar arrangement can be made out under the high power. The individualised inclusions are mainly referable to ægirine, similar to that occuring as an essential constituent of the rock. It is recognisable by its marked and characteristic pleochroism. Occasional grains of magnetite also occur. Besides these, there are indeterminate dusty inclusions of a greyish colour. In one very large crystal is included a fragment of the felspathic material to be described later. Another large, almost basal, section shows a very remarkable inclusion. The nepheline is about 1·58 mm. in diameter, in it is a crystal of sanidine, ·53 mm. long by ·118 mm. broad. The sanidine is singly twinned, and has given rise to cleavage cracks (parallel to $[10\bar{1}0]$) in the host (*Plate* I, fig. 4). This occurrence is remarkable, as the crystallisation of sanidine is usually subsequent to that of nepheline. The essential felspar is present in small quantity, and is inconspicuous.

It occurs in exceedingly slender lath-shaped sections about ·125 mm. long by ·007 mm. broad. Some of these are distinctly singly twinned, as observed with a ⅙th inch objective, have a refractive index somewhat lower than that of Canada balsam, and exhibit the characteristics of sanidine. On the other hand, as observed by Mr. G. W. Card, some of the felspar microlites extinguish at an angle of about 10° measured from the clinodiagonal or brachy-diagonal, on the assumption that the microliths have been elongated in the direction of that axis. This points to the probability that some, if not all, of the felspar microliths are not normal sanidine. They may be soda-bearing varieties or even albite. The principal ferromagnesian constituent of the rock is ægirine. In reflected light most of the pyroxene is seen to be somewhat decomposed, possessing a light greenish-yellow colour, but where undecomposed it is blackish-green. In transmitted light the colour is dark green. Many of the individuals are almost opaque owing to decomposition products. The habit is prismatic, the larger prisms being conspicuously frayed out at the ends. Besides the prisms, there are numerous tufty aggregates with a slight tendency towards radial spherical arrangement. The pleochroism is very strong in brown and dark blue-green tints. The extinction angle is small, not more than 4° or 5° from the axis of the prism, but exact measurements are rather difficult to make. The maximum length is about ·25 mm., and the smallest individuals sink to microlitic dimensions. A very small quantity of biotite is also present of same order of size as the larger ægirines, and its pleochroism is in dark greenish bronze to opaque. A little magnetite is scattered through the section. Mr. G. W. Card suggests that some of the curved microlites may be melilite.

The most remarkable feature of the rock is the abundance of included fragments. In ordinary light these are colourless but somewhat clouded by decomposition products which appear opaque white in reflected light. The double refraction of these is stronger than that of nepheline. The refractive index is lower than that of Canada balsam in the cases where a comparison is possible

(Becke's method). These facts indicate an acid felspar. These felspar fragments are much broken up through mechanical and chemical agencies, and polarize as a mosaic. Extensive corrosion has gone on, many of the grains having been almost entirely dissolved, but no difference in the character of the rock can be seen in the neighbourhood of the enclosure. One idiomorphic crystal was found having the outline of a clinopinacoidal section of felspar with [001] extensively developed, and [110] and [201] less so. Owing to the extent of decomposition and alteration no exact determinations of this felspar are possible. These inclusions are almost certainly derived from the granite through which the dyke has been intruded. If this is so, the occurrence of such felspathic material in the larger nephelines is additional evidence *against* the intratelluric origin of the latter. In the large amount of enclosed granitic material the Kosciusko nepheline rock resembles some of the other dyke rocks of this district, the olivine basalts being particularly rich in granite enclosures.

No. 4 does not differ essentially from No. 1, except that it is considerably more decomposed. As a result of this decomposition several new minerals have made their appearance, namely, analcite, calcite, and natrolite. They possess a pseudo-amygdaloidal arrangement. The analcite is slightly greenish in colour, owing to chloritic stains, but is perfectly isotropic and characteristic in every other particular. The calcite also calls for no particular remark. The mineral we have called natrolite occurs in the form of little tufty aggregates with a tendency towards spherulitic arrangement, and is included in the analcite. These fibres possess a refractive index not distinguishable from that of the analcite. The double refraction is quite noticeable, even though the fibres do not extend through the whole thickness of the section, the colours being greyish-white. The extinction is parallel and at right angles to the length of the needles.

The felspathic inclusions are, if anything, more abundant here than in No. 1, but possess similar characters slightly modified by the greater amount of decomposition. In addition to the

felspathic inclusions there are one or two included fragments of greenish-brown biotite, which are corroded though not to the same extent as the felspar. These fragments, derived probably from the granite, intruded by the dyke, are to be distinguished from the accessory authigenic biotite of the dyke rock. The chemical analyses given below show the presence of some chlorine. This indicates sodalite as a constituent mineral, but there is no confirmatory microscopic evidence as to its presence. It is quite probable that some of the material noted as "glass" should be referred to this mineral.

No. 3 specimen from the centre of the dyke. This rock is so distinct from those hitherto studied as to belong to quite a different rock-type. It is *holocrystalline*, though finely so. Flow structure, if present, is very obscure. Nepheline is apparently absent. By far the most abundant mineral in the rock is the felspar, which occurs in the form of irregular sections, which are not twinned. It is exceedingly difficult to determine which felspars belong to the dyke rock proper, and which to the included granite. Some definite laths of sanidine occur, but the greater part is distinctly a plutonic acid felspar. With this felspar is associated abundant muscovite in large irregular plates. Quartz is also present in small quantities. The ægirine here differs from that already described only in its habit and in the comparative absence of decomposition.

The section as a whole is very difficult to interpret. We are inclined to think it does not represent a fair sample of the dyke rock, but rather belongs to a part of it which has had its characters entirely altered by almost complete solution of a large fragment of included granite. The plutonic character of such a large percentage of the minerals, and the occurrence of abundant muscovite is in favour of this hypothesis. The fragments which can be definitely made out to be inclusions are very numerous. Others, exceedingly like them, shade off insensibly into the groundmass. The peculiar habit of the ægirine, namely, its occurrence with the ends of the prism round or conical as if due to solution is sugges-

tive of a very marked change in the composition of the magma after their formation. The change must have taken place after the crystallization of the ægirine, but prior to that of most of the sanidine and before any nepheline had started to form. The evidence as to the nature and date of this change is we think, quite conclusive.

A short description is given here of the eruptive rocks associated with the phonolitic nephelinite:—

Granite—Three miles from Jindabyne towards Cooma, on road. Typical hypidiomorphic texture rather coarsely crystalline. Evidence of dynamical metamorphism in the undulose extinction of many of the minerals, bending of biotite flakes, the bending and faulting of twin lamellæ of felspar and the peripheral shattering of all the minerals. Quartz is abundant in irregular grains, generally much shattered at the edges. It contains plentiful liquid and gaseous inclusions arranged in very definite planes, which, at any rate in some cases, pass from grain to grain without interruption. In addition to enclosures of the older segregations which occur abundantly as rock constituents, the quartz also contains straight and curved trichites which are apparently opaque. These are in some cases at any rate arranged very regularly. In one section nearly perpendicular to the optic axis, they lie in lines making angles of 60° with one another, and therefore in all probability parallel to the faces of the primary rhombohedron. The largest of these trichites reach the dimensions of very small acicular crystals. Some of these are certainly apatite, others are probably rutile. The quartz is considerably cracked, the cracks being roughly parallel throughout the rock.

The Felspar, which in some cases exhibits traces of crystalline form, is apparently most of it plagioclase. It is twinned after the albite law, and in most cases after the Carlsbad law too. The peripheral shattering and decomposition render R.I. determinations difficult, but apparently the R.I. is higher than that of quartz, indicating a rather basic variety of plagioclase. The sections are not suitable for measurement of extinction angles. One whose shape and the absence of albite twinning indicate a plane parallel to M (010) gives an extinction angle of 22° in a positive sense from the trace of the cleavage parallel to P 001. Another section nearly in the zone ⊥ M (010) gave extinction angles for the albite lamellæ 16° and 18° on opposite sides of the plane of composition of the twin. The felspar probably lies between a basic andesine and an acid labradorite probably the latter, as the measurements in the section parallel to M (010) are the more reliable. A small quantity of a second felspar is present, which from its low R.I. (less than that for balsam) and untwinned character is probably orthoclase. The enclosures in the felspar are

zonally arranged. The trichites mentioned in the quartz do not appear to be represented, but otherwise they are similar.

Biotite is very abundant. It occurs in ragged sections which give very marked evidence of the crushing to which the rocks have been subjected. In ordinary light the colour is bright yellow on vertical sections to reddish-brown on sections near the base. Basal sections are practically opaque. The pleochroism is very intense, absorbtion of light vibrating parallel to the cleavage being almost complete. (In the thick slice this gives rise to a remarkable appearance where a thin film of biotite overlaps a section of quartz and felspar. The biotite acts as an analyser and the polarisation colours of the other mineral appear even though the upper nicol is out of the axis of the tube). The biotite flakes are fairly free from decomposition. In one or two places a little greenish chloritic material is present. One of the remarkable features of the rock is the presence of numerous aggregates of faintly bluish-green talc or sericite. These represent the decomposition products of some previously existing mineral. In one of the aggregates there is apparently a kernel of greenish-yellow epidote, showing that whatever may have been the character of the primary mineral, epidote was one of the alteration products. The aggregates are parallel tufted and irregular. It is obvious that there has been an increase of bulk during the process of decomposition which gave rise to the talcose mineral, since the surrounding minerals have been very much broken up by cracks radiating from the aggregates and the talc (?) has been injected irregularly through these cracks.

Among the accessory minerals other than the rutile and apatite already mentioned, are apatite (in larger prisms) zircon and pyrites.

The apatite is fairly abundant, particularly as inclusions in the biotite. In one case an apatite, itself an inclusion in the biotite, includes a well developed zircon.

Zircon is remarkably abundant, especially in the biotite, where it produces very strongly marked pleochroic halos.

Pyrites occurs in two distinct habits, (i.) as small dusty grains which accompany the regularly arranged fluid and gaseous enclosures of the quartz; (ii.) larger tufts and perfect cubical (pyritohedral) crystals scattered through the rock.

Basalt from between Boggy Plains and Pretty Point Kosciusko. This rock has a pilotaxitic base, with marked flow structure composed of felspar and brownish augite microlites with a lot of minute crystals of magnetite. There is no glass present. The felspar microlites are somewhat basic, the refractive index, as tested by Becke's method being distinctly higher than that of Canada balsam, and in some sections they have extinction angles up to about 30°, measured from the Carlsbad twinning plane. Colourless augite is present in idiomorphic stunted prisms with pyramids. They have a small opti-axial angle and good cleavage. They decompose into light green products, apparently chlorite. There are also present

more or less kaolinised and much corroded fragments of felspar with an occasional granule of quartz, both being evidently derived from rocks intruded by the basalt dyke, so that they may be considered to be enclosures. A granular greenish-yellow epidote is present with a pleochroism in grey to deep greenish-yellow. It probably represents an intermediate stage of alteration between the colourless augite and the chlorite. In one slide the basalt contained a small enclosure of kaolinised felspar with a flake of biotite intercrystallised with it. This enclosure was obviously derived from the local granite.

IV. *Chemical Composition.*—The chemical nature of the rock is shown in the accompanying table which exhibits the result of analyses (made by one of the authors, Mr. Guthrie), of the three specimens taken from different portions of the dyke, the microscopic characteristics of which have been just described. Specimen No. I. was taken from the northern side of the dyke, and represents a thickness of the dyke of six inches, measured at right angles to the plane of junction of the dyke rock with the granite. No. IV. represents a similar portion of the dyke on its southern side, and No. III. was taken from the centre of the dyke. As already stated, the dyke is about seven feet wide.

Composition of nephelinitic tinguaite from Kosciusko.

	I.	III.	IV.
Water at 100° C.	0·23	0·78	0·32
Water above 100° C.	3·54	5·25	3·29
SiO_2	52·40	50·15	51·98
Al_2O_3	19·93	18·45	20·61
Fe_2O_3	3·83	4·71	4·08
FeO	1·51	1·24	1·32
MnO	0·45	0·26	0·40
CaO	1·34	1·39	1·12
MgO	0·32	0·37	0·38
K_2O	4·10	4·65	4·42
Na_2O	11·71	12·02	11·69
SO_3	none	none	none
Cl	0·05	traces	0·09
P_2O_5	traces	traces	traces
CO_2	0·21	0·52	0·44
	99·62	99·79	100·14
Oxygen equivalent for Cl	0·01		·02
	99·61		100·12
Specific Gravity ...	2·499	2·434	2·492
Decomposible by HCl	66·0	60·0	66·0

Composition of portion decomposed by HCl.

	I.	III.	IV.
SiO_2	51·84	53·90	53·16
Al_2O_3	28·74	26·86	27·08
Fe_2O_3	2·68	3·02	2·74
CaO	1·83	1·92	1·85
K_2O	1·98	1·77	2·45
Na_2O	12·93	12·53	12·72
	100·00	100·00	100·00

A few remarks with regard to the analysis are appended. The water above 100° C. was determined by heating the powdered rock in a hard glass tube, the water being collected and weighed in a small bulb-tube containing calcium chloride. The mass after fusion with sodium carbonate was in all cases of a bright green colour, dissolving in acid to a pink-coloured solution. The iron and alumina were separated from the manganese by precipitation as basic acetates, and the manganese determined by the method described in Bulletin 148 of the United States Geological Survey by W. F. Hillebrand. The ferrous iron was determined by treating the rock with hydrofluoric and sulphuric acids in an atmosphere of carbon dioxide.[1] We are indebted to Mr. Mingaye, Assayer and Analyst to the Mines Department, Sydney, for a sample of hydrofluoric acid of almost absolute purity.

The portion of the rock decomposed by hydrochloric acid was attacked in the following manner: 1 gramme of the finely powdered rock was digested with strong hydrochloric acid (sp. gr. 1·1) for a few minutes. The solution was diluted with about four times its volume of water, boiled for 10 minutes, and filtered. The filtrate, which contained dissolved SiO_2, was evaporated to dryness, ignited on the water-bath and taken up with hydrochloric acid, the separated SiO_2 being filtered off, ignited and weighed; the iron, alumina, lime and alkalies being determined in the filtrate. The residue originally insoluble in hydrochloric acid and which

[1] J. H. Pratt—Amer. Journ. Sci. (3) 48, 149.

contains deposited silica from the decomposition of the nepheline, was treated with 30 cc. of 10 per cent. solution of NaHO. It was boiled for about two minutes, diluted, and filtered through a weighed filter-paper. The residue dried at 100° C. and weighed, gives the amount unattacked by hydrochloric acid. The alkaline filtrate was acidified, evaporated to dryness and the silica determined in the usual way. We thus obtain the proportion of silica separated out when the rock was attacked by HCl as well as the proportion which went into solution in the acid. These were added together and entered in the analysis as SiO_2 decomposable by HCl. If stated separately they are as follows:—

	I.	III.	IV.
Separated SiO_2 ...	46·73	46·88	46·91
Dissolved SiO_2 ...	5·11	7·02	6·25
	51·84	53·90	53·16

With regard to the distribution of the different minerals in the rock, Mr. Card has kindly given us the results of his calculation. He finds the following to represent roughly the percentage mineral constitution of the rock according to the analytical data, taking as a basis the mean of the three analyses:—

Felspar (orthoclase and albite = soda-orthoclase)...	45·4
Nepheline	33·6
Ægirine-augite	21·0
	100·0

The assumptions made are the following:—

1. The whole of the Fe_2O_3 is contained in ægirine.
2. The FeO and MgO are contained in a pyroxene together with the CaO.
3. A MnO SiO_2 molecule is present.

The whole forming an ægirine-augite of the composition—

$$\left\{\begin{array}{l} Na_2O.\ Fe_2O_3.\ 4\ SiO_2. \\ (FeO.\ MgO)\ CaO.\ 2\ SiO_2. \\ MnO.\ SiO_2 \end{array}\right.$$

4. The proportion of K_2O to Na_2O in the nepheline is 1 : 5.

On these assumptions the whole of the material in the rock is exactly accounted for with the exceptions that there remains a residue of about 1 per cent. Na_2O, and that 0·2 per cent. CaO is required above that present in the rock. This is shown by the table on the next page, in which the percentage amounts of the different ingredients are accounted for, taking the following formulæ for the minerals present:—

Orthoclase and sanidine ($K_2O.\ Al_2O_3.\ 6\ SiO_2$)

SiO_2	64·75
Al_2O_3	18·35
K_2O	16·90
	100·00

Albite ($Na_2O.\ Al_2O_3.\ 6\ SiO_2$).

SiO_2	68·70
Al_2O_3	19·47
Na_2O	11·83
	100·00

Nepheline ($K_2O.\ 5\ Na_2O.\ 6\ Al_2O_3.\ 12\ SiO_2$).

SiO_2	41·48
Al_2O_3	35·25
Na_2O	17·85
K_2O	5·42
	100·00

Ægirine ($Na_2O.\ Fe_2O_3.\ 4\ SiO_2$).

SiO_2	51·95
Fe_2O_3	34·63
Na_2O	13·42
	100·00

$RSiO_3$ ($MgO.\ 2\ FeO.\ 3\ CaO.\ 6\ SiO_2$).

SiO_2	50 56
FeO	20·22
MgO	5·62
CaO	23·60
	100·00

$MnSiO_3$ ($MnO.\ SiO_2$).

SiO_2	46·15
MnO	53·85
	100·00

The last three minerals forming an ægirine-augite, and the first two a soda-potash felspar.

Mean percentage composition of the rock.

SiO_2	51·51
Al_2O_3	19·66
Fe_2O_3	4·21
FeO	1·32
MgO	0·36
CaO	1·28
Na_2O	11·81
K_2O	4·39
MnO	0·37
Distributed as follows:—	94·91

	Mean Percentage.	Soda-potash Felspar. Orthoclase.	Albite	Nepheline.	Ægirine.	$RSiO_3$	$MnOSiO_2$	Total.
SiO_2	51·51	9·88	17·84	13·85	6·32	3·30	0·32	51·51
Al_2O_3	19·66	2·80	5·06	11·77	...	...	...	19·63
Fe_2O_3	4·21	...	...	...	4·21	...	...	4·21
FeO	1·32	...	...	...	...	1·32	...	1·32
MgO	0·36	...	...	...	...	0·36	...	0·36
CaO	1·28	...	...	...	...	1·54	...	1·54
Na_2O	11·81	...	3·07	5·96	1·63	...	...	10·66
K_2O	4·39	2·58	...	1·81	...	...	...	4·39
MnO	0·37	...	...	...	...	...	0·37	0·37
	94·91	15·26	25·97	33·39	12·16	6·52	0·69	93·99

The difference (0·92) between the totals as calculated in the last column and the amounts present in the rock being due to the excess of Na_2O (1·15) and Al_2O_3 (0·03) and to the deficiency of CaO (0·26).

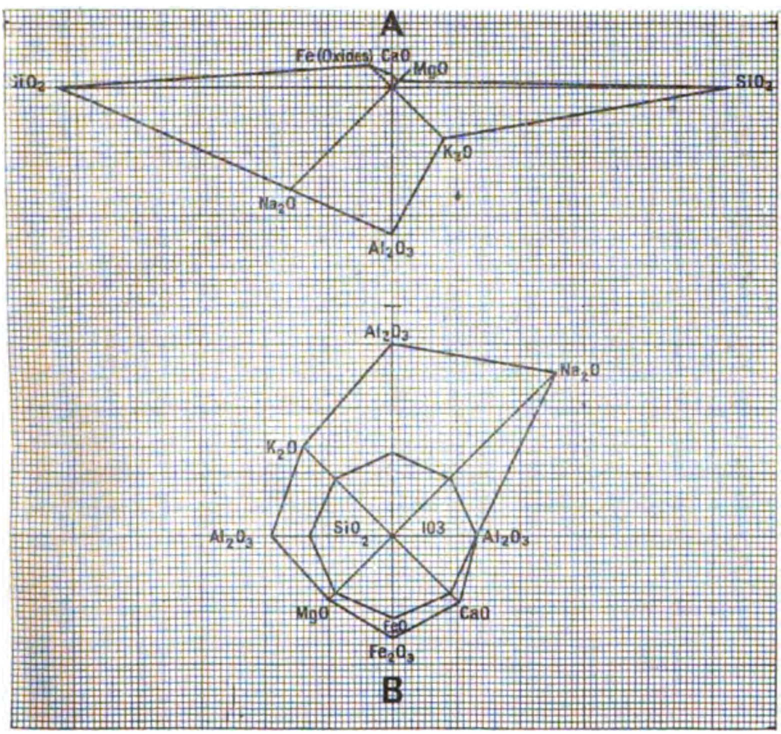
Reducing these figures to percentages we get the following as the approximate composition of the rock:—

Orthoclase and sanidine ...	16·2	43·8 soda-potash felspar
Albite	27·6	
Nepheline...	35·6	
Ægirine	13·0	20·6 ægirine-augite
$RSiO_3$	6·9	
MnO SiO_2	0·7	
	100·0	

A result which agrees fairly closely with Mr. Card's calculation.

No attempt has been made to distribute the minerals in the portion soluble in HCl. Nearly the whole of the iron in the original rock has apparently gone into solution, and if this is all contained in the ægirine as has been assumed in the above calculation, the ægirine must have undergone a selective decomposition, as the figures do not permit of the assumption that the soluble part consists of nepheline with some ægirine.

Mr. Card has also very kindly prepared for us the following diagrams, to express graphically the molecular constitution of the rock.



A. is a Brögger diagram as modified by Hobbs, (Journ. Geol. VIII.)
B. is a Mügge diagram (N.J.B., 1900, Vol. I.)

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	BaO	Water	Loss.	Cl	So_3	P_2O_5	Co_2	
Phonolite Rock, Black Hills, Dakota.	61·08	0·18	18·71	1·91	0·63	trace	1·58	0·08	8·68	4·63	0·05	2·21	...	0·12	trace	...	...	L. V. Pirsson, Amer. Journ. Sci., [3] XLVII, p. 341.
Phonolites from Colorado Florissant, Pasolty Co., Colorado. 25°/o soluble in HCl=nepheline.	60·02	...	20·98	2·21	0·51	trace	1·18	trace	8·83	5·72	...	0·70	...	trace	...	trace	...	100·15. L. G. Eakins, (v. W. Cross) Jahr. f. Min., 1890, 1 Ref Sci. Soc, 1887, II., 167
Phonolite from Teplitz-Schlossberg in Bohemia	58·16	...	21·57	2·77	...	0·24	2·01	1·26	5·97	6·57	...	2·08	...	...	0·16	...	...	100·58. Rammelsberg, Z. Geol. Ges. XIV, 1862, 751; XX., 542.
Tinguaite from Edda Gijorgis, Abyssinia.	57·81	...	18·74	5·76	0·42	trace	1·58	trace	9·35	4·52	...	...	1·50	...	...	...	...	99·38. G. T. Prior, Min. Mag. XII., 57, 269, July 1900.
Phonolite of the Volcanic Vent of Traprain Law at East Lothian.	56·8	0·5	19·7	2·2	3·5	0·2	2·2	0·4	4·3	7·1	...	...	2·5	...	...	...	..	F. H. Hatch, Trans. Roy. Soc. Edinburgh, 1893, XXXVII., p. 115.
Wolf Rock	56·46	...	22·29	2·70	·97	trace	1·47	trace	11·13	2·81	...	2·05	...	...	...	trace	...	Phillips, by Allport, Geol. Mag. VIII., 1871, p. 249.
Greenland Harbour, Kerguelen Island.	54·87	...	21·64	3·31	0·89	trace	1·63	0·37	9·26	4·02	...	3·61	...	...	...	...	...	99·60. Clement, in Renard's Report of the Petrology of Oceanic Islands, 1889, 134.
Laurdalite. Type rich in nepheline, Lunde, Lougenthal, Christiania District.	51·90	not deter.	22·54	4·03	3·15	not deter.	3·11	1·97	8·18	4·72	...	0·22	..	...	...	not deter.	...	99·82. G. Forsberg, Zeitschr. f. Kryst. B. 16, I., 33. See also Die Eruptiv-Gesteine des Kristiania-Gebietes W. C. Brögger, III., p. 19.
Nephelinitic tinguaite var Muniongite, Kosciusko, New South Wales.	51·51	...	19·66	4·21	1·36	·37	1·28	·36	11·81	4·39	...	·44	3·52	·05	trace	trace	·39	F. B. Guthrie, Journ. Roy. Soc., New South Wales, XXXV., 1901.
Nepheline-phonolite, Purakanui, near Dunedin New Zealand. 51·8°/o soluble in HCl.	51·15	...	$\underbrace{\quad\quad}_{29·38}$		...	trace	4·59	0·34	13·80	0·95	...	...	...	...	...	...	...	100·21. F. B. Allen and P. Fitzgerald, Austr. Assoc. Adv. Sci., Chrischurch, 1891, III., 136.
Nepheline-porphyry, Lougenthal.	50·63	0·90	24·00	2·33	2·21	...	2·13	1·54	11·36	4·39	...	0·63	...	...	...	0·28	...	100·40. W. C Brögger, Die Eruptiv-Gesteine des Kristiania-Gebietes, III., p. 235.
Nephelinite of the Katzenbuckel in the Odenwald.	48·24	...	20·72	6·24	3·58	CoO and NiO 0·23	2·88	2·32	11·00	4·43	...	1·50	...	...	0·18	...	...	H. Rosenbusch, "Der Nephelinit vom Katzenbuckel.' Inaug. Dis. Freiburg 1869; Neues Jahr. f. Min. 1869; S. 467.
Nepheline-porphyry of Beemerville, Sussex Co. N. Jersey. (Sussexite of Brögger).	45·18	...	23·31		$\overbrace{\quad\quad}^{6·11}$		4·62	1·45	11·17	5·95	...	1·14	...	...	...	...	...	98·93. J. F. Kemp, "The Elæolite Syenite near Beemerville, Sussex Co., N.J." Trans. New York Acad. Sci., II., 60, 1892.

V. *Relation to allied rocks.*—The foregoing table shows the relation of the Kosciusko rock, from the point of view of its chemical composition, to various nepheline-bearing rocks from other parts of the world.

It is obvious from the preceding table that (if we omit, on account of its deficiency in potash, the phonolite of Purakanui near Dunedin, New Zealand), there are three nepheline rocks in the table to which the Kosciusko rock is, chemically, closely allied, viz., (1) The nepheline-porphyry (Brögger) of the Lougenthal, Christiania District. (2) the type of Laurdalite (Brögger) rich in nepheline, from Lunde in the Lougenthal, and (3) the phonolitic nephelinite of the Katzenbuckel in the Odenwald. The Kosciusko rock is slightly poorer in alumina, lime and magnesia than the two Lougenthal rocks, and is slightly more acid than the phonolitic nephelinite of the Katzenbuckel which contains 48·24 per cent. of silica, as compared with 51½ per cent. in the Kosciusko rock.

Mineralogically the characteristics of these three rocks may be summarised as follows:—(1) Nepheline porphyry of the Lougenthal[1] The rock consists of a medium grained ground-mass, with a perfect eugranitic structure with larger or smaller phenocrysts (einspringlingen) up to 3 cm. in diameter of nepheline in stunted prismatic crystals, bounded by the faces (0001) and (10$\bar{1}$0). Very sparingly imbedded in the base are irregularly bounded poikilitic plates of biotite and slightly idiomorphic individuals of felspar. The ground-mass, which is composed of granules having an average size of 2 to 5 mm., is formed of soda-orthoclase (cryptoperthite) and orthoclase-microperthite, both of the same size and passing into one another : it also contains nepheline and sodalite, but the latter mineral occurs more sparingly. Amongst the darker minerals are ægirinediopside with an outer zone of ægirine, and biotite (it may be lepidomelane) together with accessory titaniferous iron, pyrites, sphene and apatite.

[1] Description abridged by us from Brögger's "Die Eruptivgesteine des Kristianiagebietes," Vol. III., pp. 155 - 161.

Brögger calculates *(op. cit.*, p. 161) the mineral constitution of this nepheline porphyry to be as follows:—

40½	Alkali-felspar
32½	Nepheline
11	Sodalite
8	Pyroxene
5	Lepidomelane
2	Iron oxides
1	Sphene
½	Apatite
100	

The nepheline porphyry therefore of the Lougenthal differs from the Kosciusko nepheline rock in being (1) much more coarsely crystalline, being eugranitic in texture, in which respect as Brögger remarks, it approaches the nepheline syenites to which he has applied the name of ditroite. (2) In containing some phenocrysts of felspar. (3) In containing more sodalite. (4) In containing more mica. (5) In containing sphene, which does not appear to be present in the Kosciusko rock. (6) In containing less nepheline than the Kosciusko rock.

A remark of Brögger with reference to this nepheline-porphyry is so applicable to the Kosciusko rock, and bears so directly on the question as to whether the Kosciusko rock can truly be termed porphyritic or not, that we think it well to quote it here *(op. cit.*, p. 157):—

"Wenn oben, wie in früheren Publicationen, das Gestein als Nephelinporphyr bezeichnet ist, muss ich hier eigentlich eine Reservation einschalten, Es is nämlich offenbar, dass die scheinbaren grossen Einsprenglinge *Keine Scharf getrennte ältere Generation im Vergleich mit den Nephelinkörner der Grundmasse darstellen. Sowohl die scheinbaren Einsprenglinge als die Nephelinkörner der letzteren sind nämlich gewiss im wesentlichen gleichseitig gebildet.*"

Also *(op. cit.*, p. 157) "Uberhaupt is diese structur, welche ganz analog auch bei dem Laurdalit selbst wiederkehrt, keine echte Porphyrstructur mit zwei getrennten Generationen, Sondern nur *eine porphyrähnliche eugranitische Structur.*" The italics in the above two quotations are ours.

As regards laurdalite (Brögger) this rock is characterised in its type localities (Brögger, *op. cit.*, p. 15) by large hypidiomorphic felspars having a subparallel arrangement and large hypidio-

morphic granules of elæolite. In another variety the nephelines are small, fairly idiomorphic and enclosed in the felspars, or intergrown with them so as to form a micropegmatitic structure. In another variety of laurdalite olivine is present in some quantity, so that Brögger applies to the rock the term olivine-laurdalite. While therefore the laurdalite of the type rich in nepheline (type III., Brögger, *op. cit.*, p. 19) differs chemically from the Kosciusko nephelinitic tinguaite in containing less soda but more lime and alumina, it differs distinctly mineralogically (1) in containing much felspar (up to over 62% in the leading type). (2) In containing little nepheline, only 13% in the leading type, though no doubt more in variety III., which is described as rich in nepheline. (3) In containing more mica. The Kosciusko rock cannot therefore be classed with nepheline-laurdalite. As the nepheline-porphry of Beemerville, Sussex Co., N.J. ("Sussexite" of Brögger) is rather too basic to be closely allied with the Kosciusko rock, there remain only the "Phonolitic nephelinites" (Rosenbusch), and certain nepheline-bearing types of tinguaite, to which the Kosciusko rock may be referred.

The phonolitic nephelinite of Rosenbusch is a trifle more basic than the Kosciusko rock, as already remarked having 2% less silica, about 4% more iron oxides, over 1% more lime, and about 2% more magnesia. Unfortunately we have not access to Doelter's paper on the phonolitic nephelinite of S. Antão. The petrological description of it, however, given by Rosenbusch[1] leads us to suppose that it must be very closely allied to the Kosciusko rock, though more basic in composition. As mentioned by Rosenbusch, the rock described by Doelter is remarkable for the absence of augite, the want of coloured minerals as constituents, the abundance of ægirine, in the form of microliths, and of sharply idiomorphic nepheline, belonging to two distinct generations. Sanidine occurs sparingly or more abundantly in small laths. The structure is decidedly porphyritic and the rock is

[1] Mikroskopische Physiographie der Massigen Gesteine.—H. Rosenbusch Bd. II., 2nd Edit, pp. 734-795.

conspicuously green. This description exactly fits the Kosciusko rock with the exception that (1) it is doubtful whether two generations of nepheline are present in the Kosciusko rock, though at first sight there appear to be. Brögger's remark about the nepheline-porphyry of the Lougenthal, we think, is applicable to the Kosciusko rock, in which we are of opinion, in spite of its porphyritic appearance, that only one generation of nepheline is present. (2) The Kosciusko rock is rather brown tinged with green, like a typical phonolite, than "conspicuously green."[1]

As the microliths of felspar present in the Kosciusko dyke rock belong to an alkali felspar rather than to a lime-soda or lime felspar the rock cannot be classed with the nepheline tephrites, and it is too basic to be grouped under grorudite or sölvsbergite. The nepheline-tinguaites, however, have much closer affinities with the Kosciusko rock. At the same time as regards structure the rock is rather nephelinitic than tinguaitic. Some tinguaites which when rich in nepheline approach in character to the Kosciusko rock have been described by G. T. Prior[2] from the neighbourhood of Adowa and Axum in Abyssinia. The Abyssinian tinguaites are, however, more acid than that of Kosciusko containing nearly 58% of silica as compared with the $51\frac{1}{2}\%$ in the Kosciusko rock.

The provisional conclusion arrived at by us is that this Kosciusko rock does not exactly resemble any definite type of rock known to us from other parts of the world with the exception of the nepheline-ægirine-alkali-felspar rock of Barigan in New South Wales.

As the rock is distinctly hypabyssal and intermediate between the (plutonic) nepheline-syenites and the (volcanic) phonolites we have decided to group it provisionally with the tinguaites rich in nepheline, and propose to call it nephelinitic tinguaite, *var.*

[1] Recent observations in the Barigan district near Lue, N. S. Wales, convince us that the brownish tinge of the Kosciusko rock is simply due to weathering and that the rock at a slight depth would be distinctly green.

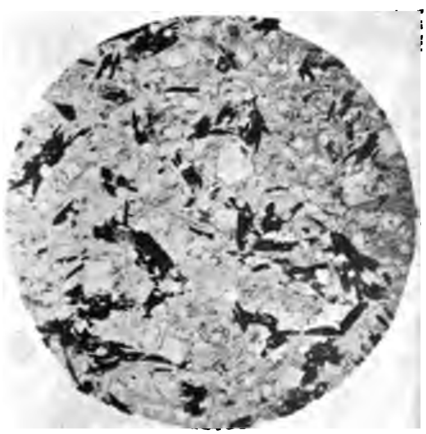
[2] Min. Mag., XII., 57, pp. 268-269, July 1900.

1

2

Fig. 1. General aspect of the nephelinitic tinguaite of Kosciusko in ordinary light. The dark aggregates are ægirine-augite. The white rectangular or hexagonal patches are nepheline. × 17 diameters.

Fig. 2. The above rock seen under crossed nicols. × 17 diameters.

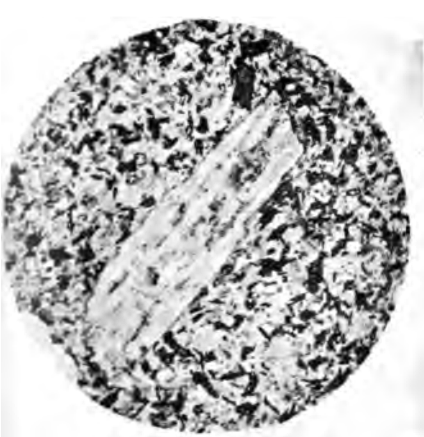


3

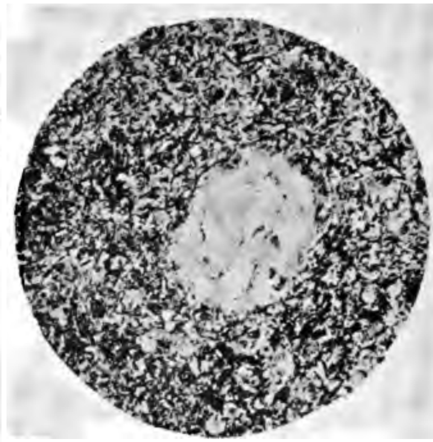
4

Fig. 3. Similar to Fig. 1 but × 35 diameters.

Fig. 4. Twinned crystal of sanidine ·53 mm. × 118 mm. Enclosed in a pseudo-porphyritic crystal of nepheline, in the nephelinitic tinguaite of Kosciusko.



1



2

Fig. 1. Felspar crystal, derived from granite, enclosed in the nephelinitic tinguaite of Kosciusko. × 17 diameters.

Fig. 2. Granule of quartz, derived from granite, enclosed in the nephelinitic tinguaite.

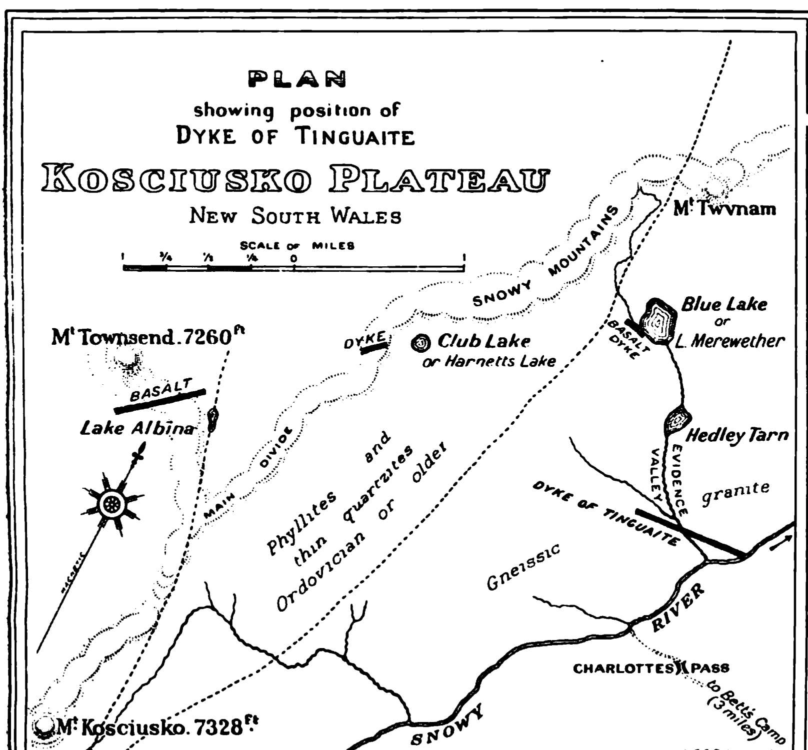


Fig. 3.

Muniongite, "Muniong" being the native name for the Kosciusko Plateau.[1]

VI. *Age.*—Lastly as regards the age of the nephelinitic tinguaite of Kosciusko, it is obvious that it is of newer date than the gneissic granites which it intersects, and that it is much newer also than the sedimentary rocks containing radiolaria and graptolites, which have been intruded by the granites. These sedimentary rocks, as already stated, are of Lower Silurian (?) (Ordovician) age. The granite therefore, is Post-Ordovician, and it is obvious that the tinguaite is very much newer than the granite. This is proved by the fact that the minerals in the nepheline dyke rock are mostly remarkably fresh and free from decomposition, and in the second place by the fact that there is an entire absence of planes of foliation or cleavage from the dyke rock.

As already stated these nepheline dyke rocks of Kosciusko appear to be of approximately the same age as the basalt dykes of the same neighbourhood. There can be little doubt that the latter belong to some part of the Tertiary Era. If, as seems not improbable, the eruptions which produced the nepheline rocks of Kosciusko were synchronous with those which produced the sölvsbergite lavas of Mount Macedon, Victoria, they would then slightly antedate or be nearly contemporaneous with the "older basalts," so called, of Victoria, as according to Professor Gregory, the latter are near in age to perhaps a little newer than the Mount Macedon nepheline rocks.[2]

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[1] Since the recent important discoveries by Mr. J. E. Carne of at least eleven mountains of nepheline-orthoclase-ægirine rocks in the neighbourhood of Barigan, near Lue, it has become apparent that the Kosciusko rock is more or less closely related mineralogically and chemically to these rocks of Barigan. The Barigan rocks pass, at their margins, into a fine-grained selvage very similar to the Kosciusko rock, Possibly at a depth the Kosciusko rock would also pass into 'Bariganite.' For the present, however, we think it better to retain for it the name given above.

[2] Proc. Roy. Soc. Vict., Vol. XIV., (New Series) Pt. II., pp. 185 – 217, Pls. xi. – xvii., 1901 [published 1902.]

The older basalts of Victoria are in part of Eocene age, and in part, according to Messrs. Hall and Pritchard,[1] perhaps older, possibly Upper Cretaceous. The nepheline rock of Kosciusco may therefore, be also of Cretaceous, or at all events of Upper Mesozoic age. This conclusion is rendered the more probable by a comparison of the age of the trachyte lavas of the Canoblas near Orange, and of the Warrumbungle Mountains near Coonabarabran in New South Wales. These last appear to be slightly older than most of the Tertiary basalts of New South Wales, perhaps Eocene or older.[2]

Moreover, the relations of the soda-syenite of the Gib Rock near Bowral, New South Wales, to the Tertiary basalts of the same neighbourhood appears to be somewhat similar, the soda rock being somewhat older than the basalts. Evidence is as yet wanting as to the exact age of the rock in New South Wales, which above all others hitherto described mostly closely resembles the nepheline rock of Kosciusko, viz. that of Barigan. It is clear however, from Mr. Carne's account that the nepheline rock of Barigan has intruded the Triassic Hawkesbury Series as well as the underlying Permo-Carboniferous coal measure formation, and is therefore Post-Triassic in age.

In Queensland the trachyte lavas and trachytic volcanic necks of the Glass House Mountains, between Brisbane and Maryborough and the trachyte agglomerates of the district west of Port Mackay appear to be slightly older than most of the Tertiary basalts of Queensland. As described in the report by Mr. A. Gibb Maitland[3] the trachytic agglomerates of the Port Mackay district are to be referred to the geological horizon of the Desert Sandstone, the age of the latter being considered to be either Upper Cretaceous or Cretaceo-Tertiary.

Messrs. W. H. Twelvetrees and F. W. Petterd in their interesting account of the Port Cygnet soda-bearing rocks of Tasmania

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[1] Proc. Roy. Soc. Vict., Vol. VII., pp. 188 and 195, 1894.
[2] Proc. Linn. Soc. N. S. Wales, 1896, Pt. 2, June 24th, p. 265.
[3] Geological Features and Mineral Resources of the Port Mackay District—Parliamentary Paper C.A. 93, 1889.

have shown that these rocks have intruded the strata of Permo Carboniferous age. It is probable that they are older than the Tertiary basalts of Tasmania, but definite evidence on this point as well as on the exact relation of this soda series to the vast intrusive masses of diabase of the same island has not yet been obtained. On the whole, until more accurate evidence is available, it may be concluded that the nephelinitic tinguaite of Kosciusko is probably of Upper Mesozoic age, but may possibly be Eocene.

VII. *Summary.*—The evidence so far collected proves that a highly interesting nepheline rock, for which we propose the name nephelinitic tinguaite *var.* muniongite, is developed as a dyke rock at Kosciusko. Its chemical composition proves that it is on the border line, as regards silica percentage ($51\frac{1}{2}\%$), between the intermediate and the basic groups of eruptive rocks, and tested rigidly by its silica percentage it falls within the latter group. At the same time it is obvious that its general physical characters ally it more to the phonolites than to the nephelinites. We should have no hesitation in classing it at once as a phonolite were it not for the absence of distinct and well formed crystals of potash felspar and for the fact that it is hypabyssal. As already stated minute lath-shaped crystals of soda-sanidine or soda-orthoclase are present in some numbers in the base, but they are of the nature of microliths. They constitute perhaps about 42% of the whole rock. Nepheline is very abundant, occurring in sharply idiomorphic crystals varying in size up to about 3 mm. in length by nearly the same in breadth; in one case a crystal of sanidine was observed to be enclosed in the centre of one of these nepheline crystals. (See *Plate* I, fig. 4.)

Ægirine is also very abundant, and forms over 13% of the whole rock as compared with the 35% formed by the nepheline. The presence of 0·07% of chlorine implies that a little sodalite is also developed. The analcite observed was in every case of secondary rather than of primary origin. The same remark obviously applies to the tufted aggregates of natrolite. A little biotite is present, but much at all events is of derivative origin.

A distinct feature of this rock is the large amount of derived fragments, chiefly quartz felspar and mica, which the rock contains and which it has caught up from the gneissic granite forming the walls of the dyke. In this respect the nepheline rock of Kosciusko closely resembles the basalt dykes of the same neighbourhood. The latter contain a vast number of enclosures of granite, individual fragments being in many cases several inches in diameter. The fact of occasional crystals of sanidine being enclosed in the nepheline crystals is, we think, an argument against the intra-telluric origin, in this case, of the larger crystals of nepheline, which we therefore consider pseudo-porphyritic. The Kosciusko rock is also remarkable for the large proportion, 64%, soluble in HCl. The fact that 2·81% of the soluble portion is ferric oxide shows that part of the ægirine must have been attacked by the HCl.

On comparing the nepheline rock of Kosciusko with the soda-series of Port Cygnet, Tasmania, one is at once struck with the fact that melanite garnet, so abundant in the Port Cygnet rocks, is absent from those of Kosciusko. A possible explanation of this is afforded by the experiments of MM. F. Fouqué and Michel Lévy.[1] They state that, in their experiments in the artificial production of rocks, a mixture of 3 parts of nepheline and of 1. 3 of augite after fusion and cooling extended over two days, (following their system No. 4) produced microlites of nepheline and augite. The augite crystallised out just after the nepheline. When the proportion of pyroxene was diminished, pyroxene no longer formed. For example, a mixture of 10 parts of nepheline and 1 of augite yielded beautiful crystals of nepheline, small octahedra of spinel, and brownish isotropic rhombic-dodecahedrons of melanite garnet. Evidence is as yet insufficient as to whether or not the nepheline dyke rocks of Kosciusko are complementary to the basic dyke rocks of the same neighbourhood.

As regards age, the Kosciusko basic rocks are probably Tertiary, whereas the nepheline rocks are perhaps somewhat older, Cretaceo-

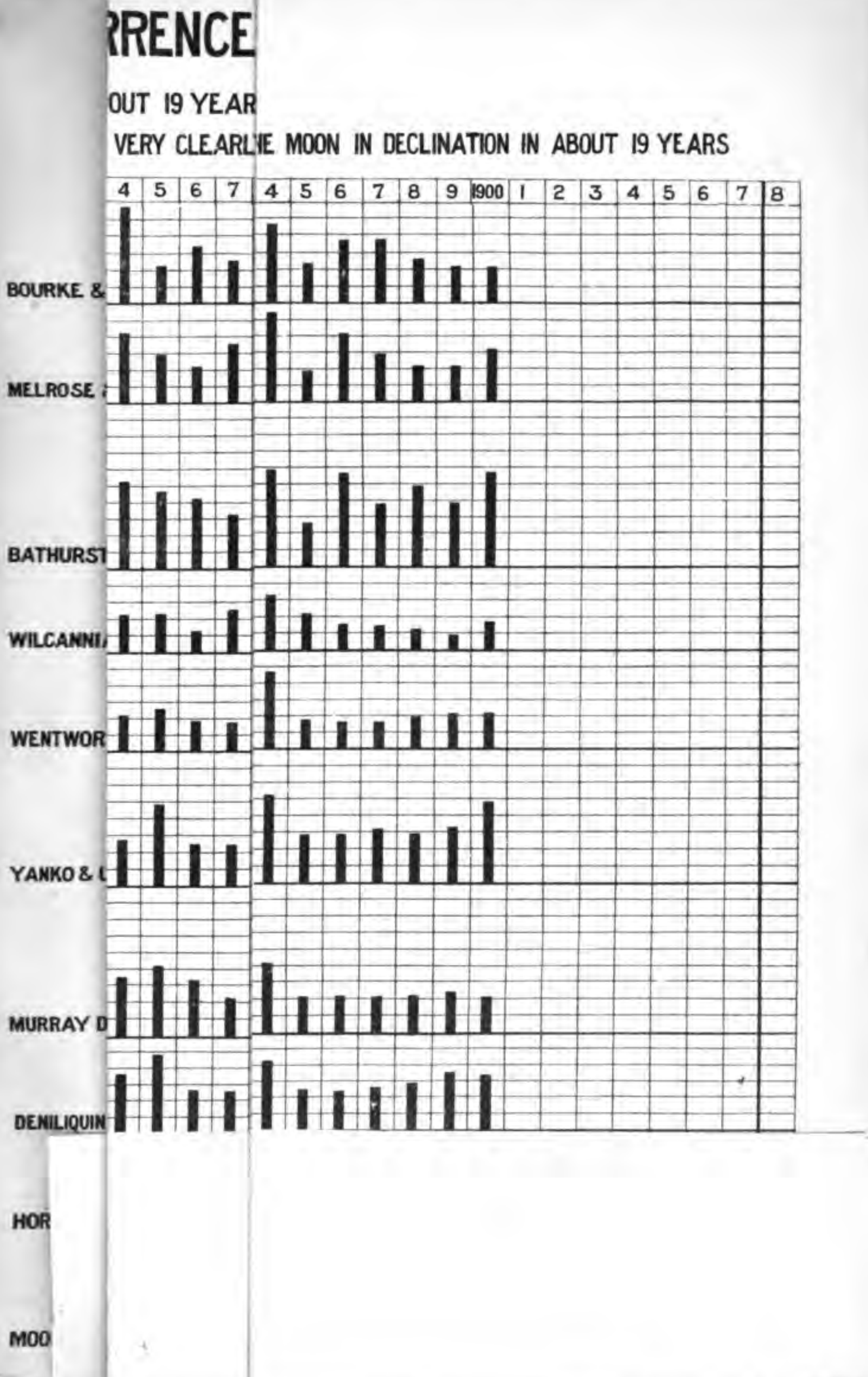
[1] Syntheseѐ des Mineraux et des Roches. Paris, 1882, pp. 63-64.

Tertiary or Upper Cretaceous. It would appear to be more than an accident that the chronological relations of the chief nepheline and younger soda-rocks to the Tertiary basalts are so similar throughout Australasia, for example, in Queensland near Port Mackay and at the Glass House Mountains; in New South Wales at the Warrumbungle Mountains, the Canoblas, the Gib Rock and Barigan; in Victoria at Mount Macedon; and in Tasmania at Port Cygnet, the nepheline and other younger soda-rocks appear in every case to be a little older than the "older Tertiary" basaltic lavas. It may be mentioned also that at Kerguelen Island the phonolites are thought to be a little older than the basalts, the latter being considered to belong to some part of the Tertiary Era, perhaps to the Miocene. It has occurred to us that there is possibly a fine field for research in studying the distribution of soda-bearing rocks (such as these nepheline rocks of Kosciusko), in relation to areas of subsidence, elevation, or stable equilibrium. So far it would appear that the extrusion of such soda rocks in Australasia has taken place chiefly along the *edges* of great subsidence areas.

It would appear then that in Australasia magmas rich in soda have risen chiefly from the septa of folds in the earth's crust rather than from the tops of ge-anticlines or from the deep seated portions of geo-synclines. The latter in Australasia have mostly yielded either basic or ultra-basic lavas or massive hypabyssal dykes, sheets, or bosses of diabase, while the former (the ge-anticlines) have produced acidic rocks such as granites and rhyolites. At the same time the fact should not be lost sight of that even the basic dyke rocks which have risen from beneath the centre of the geo-syncline under Sydney contain a good deal of soda, primary analcime being present in some of these dykes.

We are specially indebted to Mr. G. W. Card, A.R.S.M., F.G.S., for the kind help and advice he has given us of which we have freely availed ourselves. We are also indebted to him for the Mügge and Brögger diagrams. Our thanks are also due to Mr. W. S. Dun, F.L.S., for assistance in studying the bibliography of the

subject. For this portion of the paper we would specially express our obligation to the works of F. von Zirkel and H. Rosenbusch. We also desire to thank Mr. A. J. Peterson, B.Sc., and Mr. L. C. Green for their kind assistance. Our thanks are also due to Mr. E. F. Pittman, Assoc. R.S.M., the Government Geologist, for placing the Geological Survey Library at our disposal.



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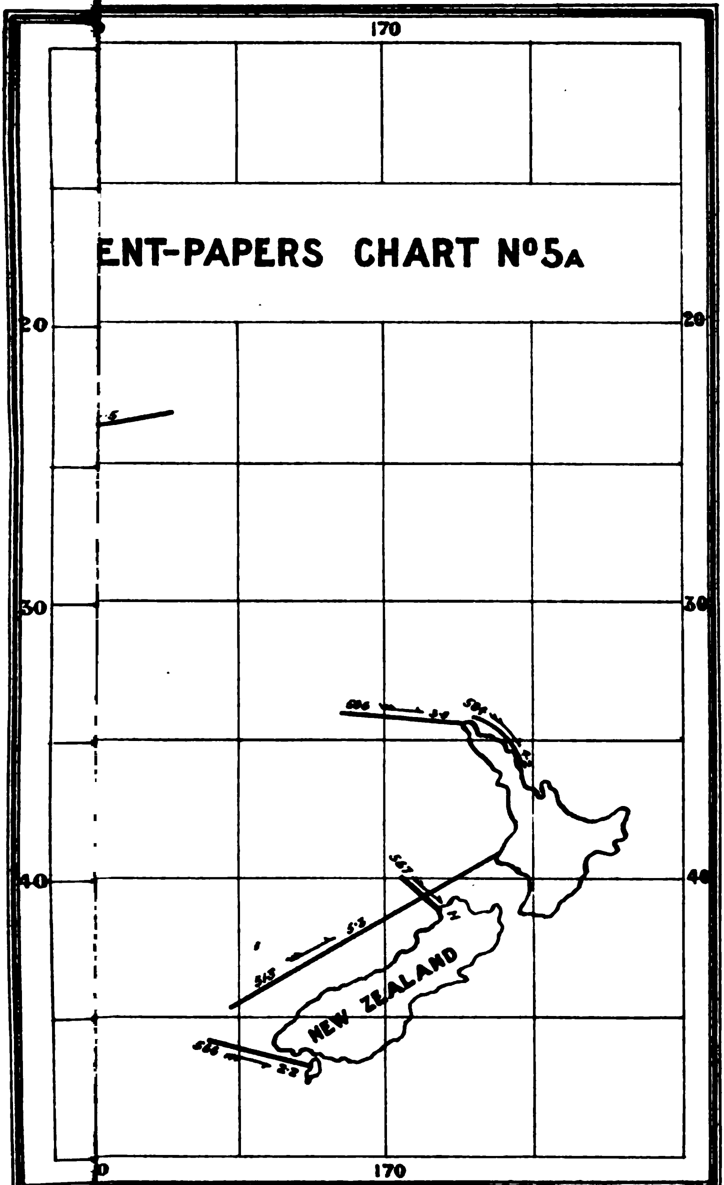

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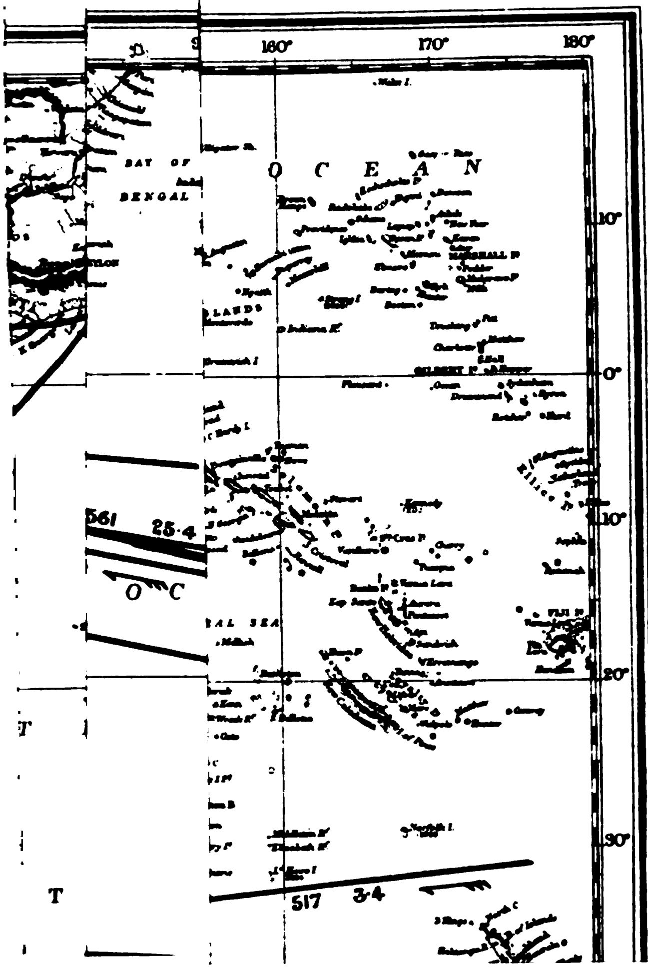

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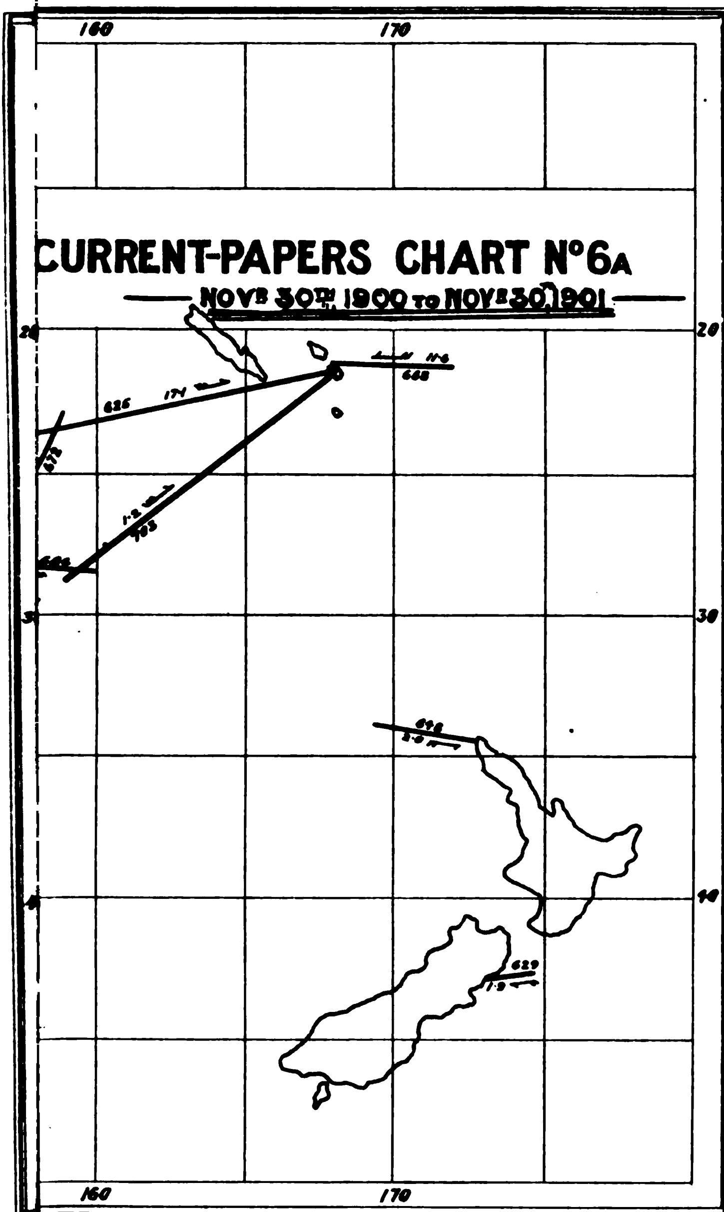
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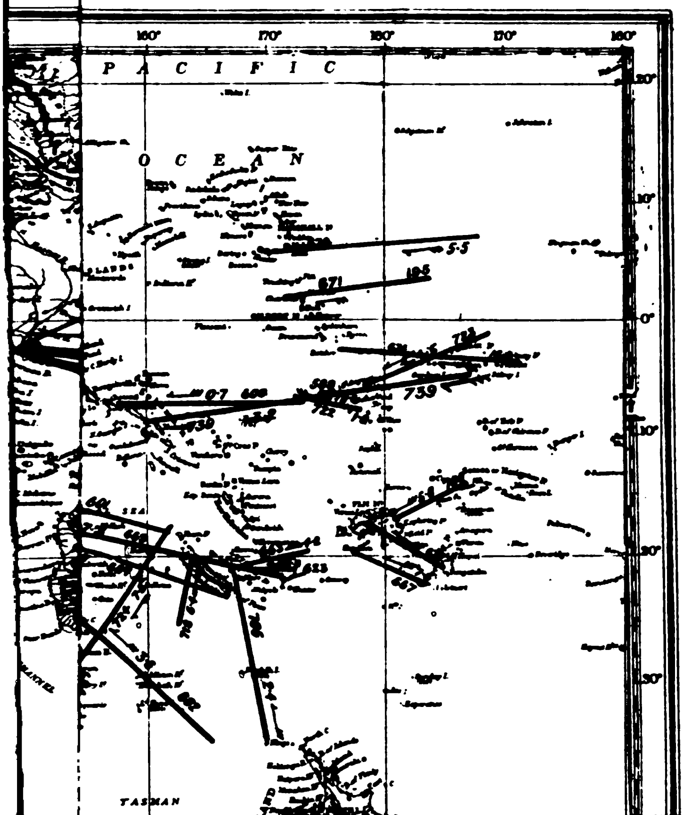
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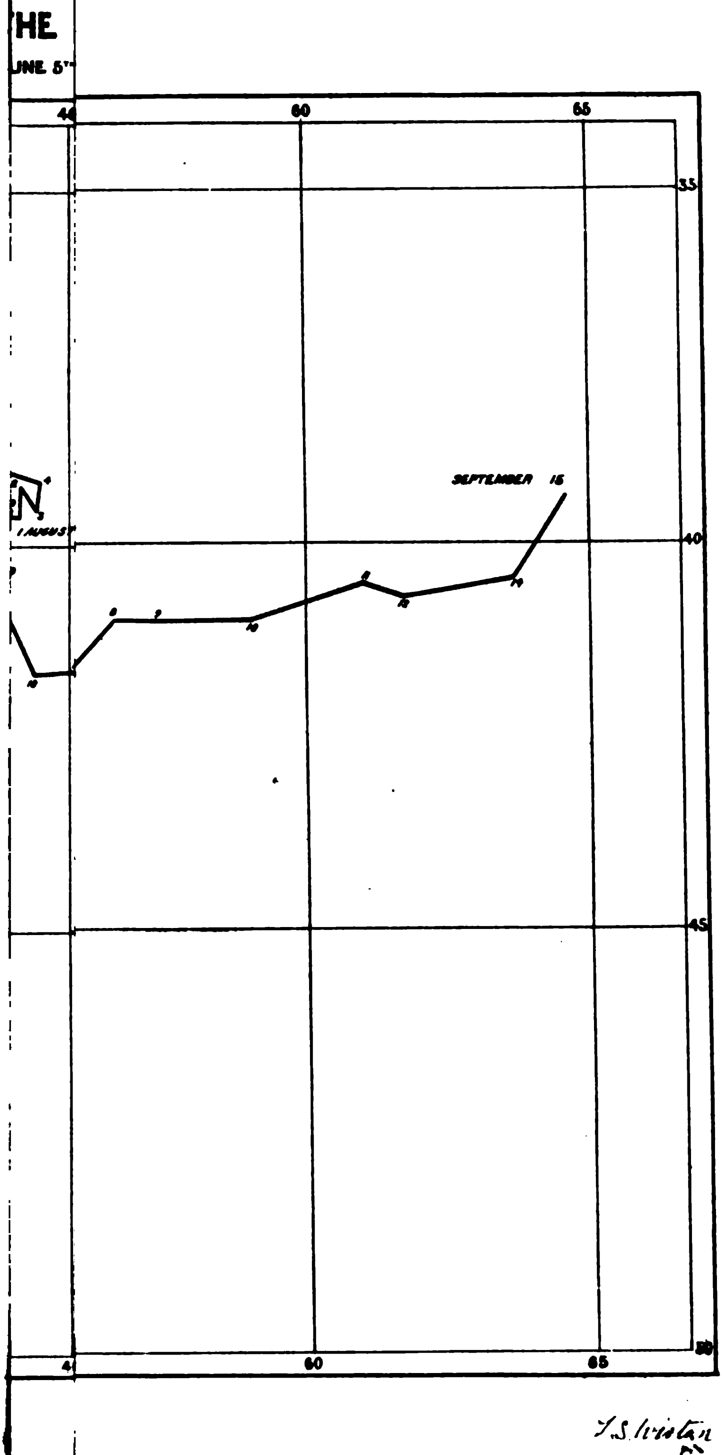

T.S. Tristan

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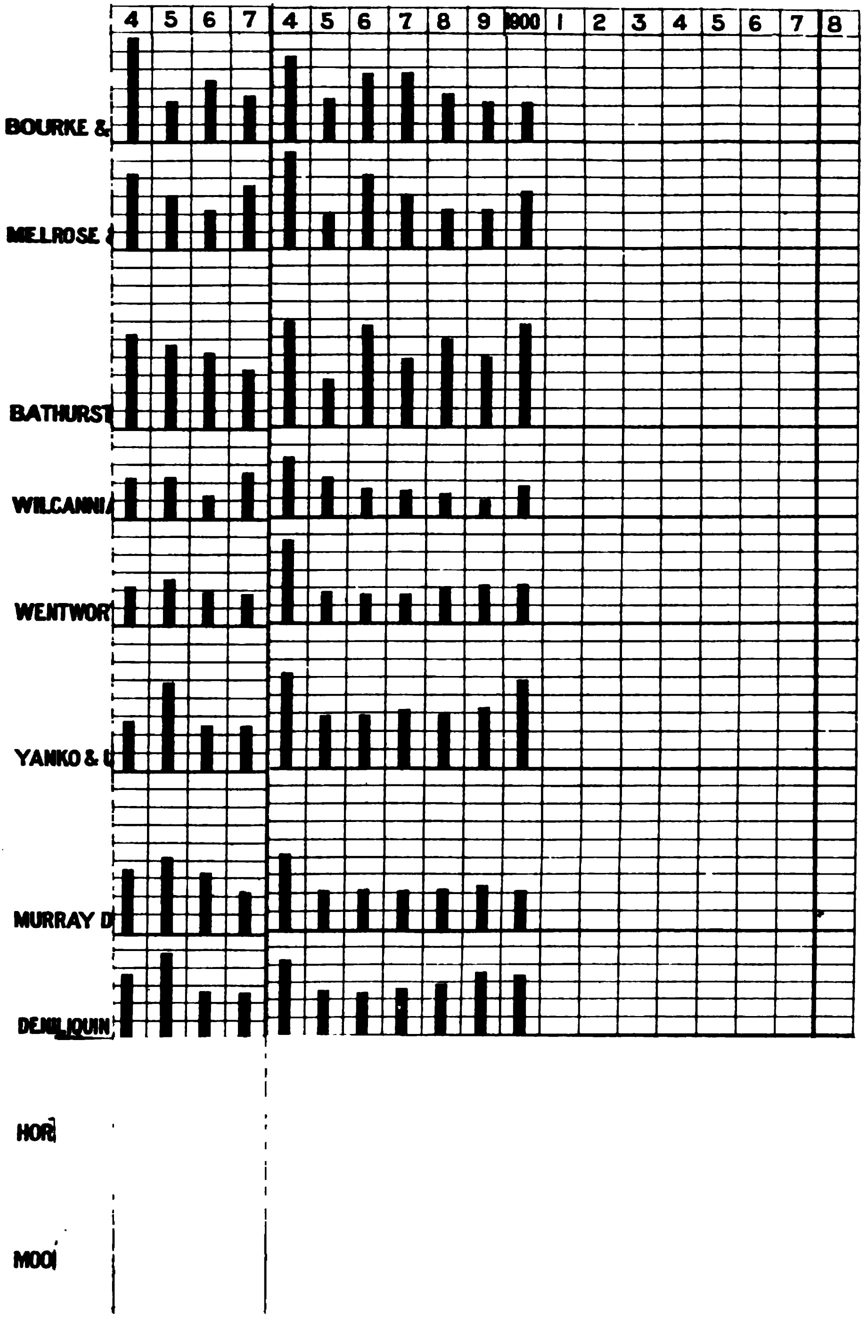
VERY CLEARLIE MOON IN DECLINATION IN ABOUT 19 YEARS



ABSTRACT OF PROCEEDINGS

ABSTRACT OF PROCEEDINGS

OF THE

The Royal Society of New South Wales.

ABSTRACT OF PROCEEDINGS, MAY 1, 1901.

The Annual General Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, May 1st, 1901.

The President, Prof. LIVERSIDGE, M.A., LL.D., F.R.S., in the Chair.

Fifty members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

The following Financial Statement for the year ended 31st March, 1901, was presented by the Hon. Treasurer, and adopted.

GENERAL ACCOUNT.

RECEIPTS.	£ s. d.	£ s. d.
Subscriptions — One Guinea	91 7 0	
Subscriptions — Two Guineas	380 2 0	
Subscriptions — Arrears	81 18 0	572 5 0
Subscriptions — Advances	18 18 0	
Entrance Fees and Compositions		25 4 0
Parliamentary Grant on Subscriptions received— Vote for 1900-1901	500 0 0	500 0 0
Rent...		17 10 0
Sundries		4 13 9
Total Receipts		1119 12 9
Balance on 1st April, 1900		36 14 5
		£1156 7 2

Payments.	£ s. d.	£ s. d.
Advertisements	21 13 0	
Assistant Secretary	250 0 0	
Books and Periodicals	106 13 8	
Bookbinding	79 8 6	
Commonwealth and Mourning Celebrations ...	12 10 1	
Freight, Charges, Packing, &c....	3 4 5	
Furniture and Effects	28 19 4	
Gas	21 18 1	
Housekeeper	10 0 0	
Insurance	6 17 4	
Interest on Mortgage	56 0 0	
Office Boy	2 2 8	
Petty Cash Expenses	16 10 8	
Postage and Duty Stamps	26 15 0	
Printing	35 14 0	
Printing and Publishing Journal	179 5 11	
Printing Extra Copies of Papers	3 18 5	
Rates	30 17 0	
Reception	6 2 5	
Refreshments and attendance at Meetings ...	19 0 6	
Repairs	10 5 1	
Shelving for Books	70 14 2	
Stationery	14 0 3	
Sundries	22 18 3	
Total Payments		1035 8 9
Repayment to Clarke Memorial Fund... ...		67 4 7
Balance on 31st March, 1901, viz.:—		
Cash in Union Bank, General Account ...	35 13 4	
" " B. & I. Fund ...	8 0 6	
Cash in hand...	10 0 0	
		53 13 10
		£1156 7 2

BUILDING AND INVESTMENT FUND.

Receipts.	£ s. d.
Loan on Mortgage at 4%	1400 0 0
	£1400 0 0

Payments.	£ s. d.
Advance to General Account 31st March, 1897	8 0 6
Balance 31st March, 1901	1391 19 6
	£1400 0 0

CLARKE MEMORIAL FUND.

Receipts.	£	s.	d.
Amount of Fund, 31st March, 1900	420	4	2
Interest to 31st March, 1901	12	12	11
	£432	17	1

Payments.	£	s.	d.
Deposit in Savings Bank of New South Wales, March 31, 1901	212	5	0
Deposit in Government Savings Bank, March 31, 1901 ...	220	12	1
	£432	17	1

Audited and found correct, as contained in the Books of Accounts.

DAVID FELL, C.A.A.......... } *Honorary Auditors.*
LAWRENCE HARGRAVE }

Sydney, 22nd April, 1901.

H. G. A. WRIGHT, *Honorary Treasurer.*
W. H. WEBB, *Assistant Secretary.*

Messrs. G. H. Halligan and T. F. Furber were appointed Scrutineers, and Mr. W. M. Hamlet deputed to preside at the Ballot Box.

There being no other nominations the following gentlemen were elected officers and members of Council for the current year:—

President:

H. C. RUSSELL, B.A. C.M.G., F.R.S.

Vice-Presidents:

PROF. T. W. E. DAVID, B.A., F.G.S.
W. M. HAMLET, F.C.S., F.I.C.
HENRY DEANE, M.A., M. Inst. C.E.
Prof. LIVERSIDGE, M.A., LL.D., &c.

Hon. Treasurer:

H. G. A. WRIGHT, M.R.C.S. *Eng.*, L.S.A. *Lond.*

Hon. Secretaries:

J. H. MAIDEN, F.L.S.
G. H. KNIBBS, F.R.A.S.

Ordinary Members of Council:

F. B. GUTHRIE, F.C.S.
H. A. LENEHAN, F.R.A.S.
CHARLES MOORE, F.L.S.
E. F. PITTMAN, A.R.S.M.
F. H. QUAIFE, M.A., M.D.
GEORGE E. RENNIE, B.A., M.D.
HENRY G. SMITH, F.C.S.
PROF. ANDERSON STUART, M.D.
J. STUART THOM
PROF. WARREN, M. Inst. C.E., Wh.Sc.

The certificates of two candidates were read for the third time, and of four for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

Enright, Walter J., B.A. (Syd.), Solicitor, West Maitland.
Little, Robert, Merchant, "The Hermitage," Double Bay.

The following announcements were made:—

1. That the Officers and Committee of the Engineering Section had been elected for the ensuing Session, and the dates fixed for their meetings as follows:—

SECTION MEETINGS.

		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
ENGINEERING—Wednesday, (8 p.m.)	... ...	15	19	17	21	18	16	20	18

SECTIONAL COMMITTEES—SESSION 1901.

Section K.—Engineering.

Chairman—J. M. Smail, M. Inst. C.E.

Hon. Secretaries — S. H. Barraclough, M.M.E., Assoc. M. Inst. C.E., H. H. Dare, M.E., Assoc. M. Inst. C.E.

Committee — Percy Allan, Assoc. M. Inst. C.E., G. R. Cowdery, Assoc. M. Inst. C.E., J. Davis, M. Inst. C.E., Henry Deane, M. Inst. C.E., J. I. Haycroft, M.E., M. Inst. C.E.I., Lee Murray, M.C.E., Assoc. M. Inst. C.E., M.I.E.E., Herbert E. Ross, W. H. Warren, M. Inst. C.E., M. Am. Soc. C.E.

Past-Chairmen, *ex officio* Members of Committee for three years:— T. H. Houghton, M. Inst. C.E., H. R. Carleton, M. Inst. C.E., and Norman Selfe, M. Inst. C.E.

Meetings held on the Third Wednesday in each month, at 8 p.m.

2. That the alterations to the rules passed at the General Monthly Meeting, December 5th, 1900, would be submitted for confirmation this evening, it being the Annual General Meeting. On the motion of Prof. Anderson Stuart, seconded by Mr. P. N. Trebeck, it was unanimously resolved that Rule II. be omitted, and the following amendments be agreed to:—

ALTERATIONS TO RULES, RECOMMENDED BY THE COUNCIL.

(Proposed at the General Monthly Meeting 5 December, 1900.)

Rule II. shall read—

Patrons and Vice-Patrons.

The Governor-General shall be invited to become Patron, and the State Governor of New South Wales, Vice-Patron of the Society.

In Rule III. delete the word "other," on the first line.

Rule XVII. shall read—The Honorary Members of the Society shall be persons of eminent scientific attainments or distinguished promoters of the objects of the Society. Every person proposed as an Honorary Member must be recommended by the Council and elected by the Society. Honorary Members shall be exempted from payment of fees and contributions: they may attend the meetings of the Society, and they shall be furnished with copies of the publications of the Society, but they shall have no right to hold office or to vote.

The number of Honorary Members shall not at any one time exceed thirty, of whom at the time of election, not more than ten (10) shall be domiciled in Australasia, and not more than three Honorary Members shall be elected in any one year.

Rule XVIII. shall be rescinded.

Rules XIX., XX., XXA., XXB., XXI., XXII., XXIII., XXIIIA., and XXIV., shall be numbered respectively XVIII., XIX., XIXA., XIXB., XX., XXI., XXII., XXIIA., and XXIII.

Rule XXV., Clause 11 shall be deleted, and clause 12 shall be numbered 11, and the Rule shall be numbered XXIV.

Rules XXVI., XXVIA., XXVIB., XXVII., XXVIII., XXIX., XXX., and XXXI., shall be numbered respectively XXV., XXVA., XXVB., XXVI., XXVII., XXVIII., XXIX., and XXX. respectively.

Rule XXXII. shall be numbered XXXIII.

Rule XXXIII. shall be numbered XXXIV.

Rule XXXIV. shall be numbered XXXV.

Rule XXXV. shall be numbered XXXVI., and shall read as follows:—

Reports from Sections.

The Secretary of each Section shall keep minutes of its proceedings. The Chairman and the Secretary shall jointly prepare and forward to the Hon. Secretaries of the Society, on or before the 21st December in each year, a report of the proceedings of the Section during that year, in order that the same may be laid before the Council.

Rule XXXVI. shall be numbered XXXI., and shall be hea Reports upon the Society's Property."

Rule XXXVII. shall be numbered XXXII.

Rules XXXVIII., XXXIX., XL., and XLI., shall be numbered XXXVII., XXXVIII., XXXIX., XL. respectively.

Forms 4, 5, and 6 shall be omitted, and Forms 7 and 8 shall e numbered 4 and 5.

The following letter was received from Sir William Crookes, F.R.S., acknowledging his election as Honorary member of the Society:

7, Kensington Park Gardens,
London, W., March 1st, 1901.

The Hon. Secretaries, Royal Society of New South Wales, Sydney.

My dear Sirs,—I feel deeply the honour done me by the President and members of the Royal Society of New South Wales in electing me an Honorary Member, and I much appreciate the complimentary words in which the information has been conveyed to me.

The knowledge that my attempts to elucidate some of the Laws of Nature in one small corner of her boundless field, are felt worthy of recognition by your old and important Society will be an additional stimulus to renewed researches on my part.

Believe me to remain, dear Sirs, very sincerely yours,
(Signed) WILLIAM CROOKES.

An informal letter, dated March 2nd, 1901, was received by the President from Sir William Turner Thiselton-Dyer, K.C.M.G., F.R.S., Director of the Royal Gardens, Kew, in which Sir William explained that he felt he could more fully and gratefully acknowledge the great honour which the Society had shown to him by electing him an Honorary Member, than in a purely formal reply.

In it he referred to the long established ties which had linked Kew to the most distant parts of the Empire, and the great pride with which he and the staff endeavoured to maintain the usefulness of that connection; he also feelingly acknowledged the sympathetic appreciation with which their efforts had invariably been received.

Also the following letter from Sir John Murray acknowledging the award of the Clarke Memorial Medal:—

Challenger Lodge, Wardie,
Edinburgh, 13th March, 1901.

My dear Sir,—A few days ago I received a letter signed by you intimating to me that the Council of the Royal Society of New South Wales had been pleased to award me the Clarke Memorial Medal in recognition of my services in the cause of Science. I shall feel very much obliged to you if you will convey to the members of the Council my very best thanks for the great honour thus conferred on me.

I very highly appreciate this recognition from New South Wales, where I spent many happy days during the Challenger Expedition. The medal arrived here to-day.

Yours sincerely,
(Signed) JOHN MURRAY.

Fifty volumes, 472 parts, 35 reports, and 7 pamphlets, total 564, received as donations since the last meeting were laid upon the table and acknowledged.

The President, before commencing the business for the evening, referred to the loss which the Society, in common with all their fellow-countrymen, had sustained by the death of their beloved and revered Queen. On receipt of the news, he, as their representative (the Society being in recess at the time), had sent a message of condolence to His Majesty the King and the Royal Family, through the kind offices of His Excellency the Governor-General. Now that the Society is in session he begged to move that a loyal address of condolence and of congratulation—for now they had to be combined—should be sent to His Majesty King Edward VII. The motion was carried unanimously.

Professor LIVERSIDGE, M.A., LL.D., F.R.S., then read his address. After referring to various matters relating to the affairs of the Society, he made the following remarks about the Library:—

"From the Balance-sheet submitted this evening it will be seen that a large proportion of our limited income continues to be spent upon the Society's Library, the Council rightly regards the up-keep of the Library as of the utmost importance; a good collection of current Scientific literature is one of the greatest necessaries of a Society of this kind; it is, in fact, absolutely essential for its work and well being, fortunately some 421 Societies and Institutions, in all parts of the world, regularly forward their publications in exchange for our Annual Volumes these, during the past year, amounted to 2,240 publications of various kinds, but we still are much in need of funds to acquire the back numbers of many Scientific Series, some of these are getting very scarce and the prices will soon become prohibitive. Especially now that so many large libraries are being formed in America and elsewhere by wealthy benefactors. Perhaps some-one in New South Wales will follow so good an example and earn the thanks of the present and future generations."

During the past year the Society had held eight meetings, at which 21 papers had been read. The average attendance of members was 35, and of visitors three. A course of five lectures had been delivered, which was well attended, and a similar course had been arranged for in the ensuing year. At a meeting held in December the rules of the Society were revised and amended. It was a matter for regret that nearly all the sections had ceased to meet, but the engineering section had continued to do good work, and it was hoped that some of the other sections would be revived and would renew their careers of usefulness. He was, however, glad to be able to announce that a section for Economic Science was about to be formed. The number of members on the roll on April 30, 1901, was 368. During the year 16 new members were elected, 8 died, and 10 resigned. The membership at present was the smallest that had been recorded since 1885. This decrease was a matter of some concern, and deserved serious consideration. It might be accounted for in part by the State not yet having recovered from the effects of the commercial

depression of a few years ago, and to the fact that there were now several societies in Sydney for special subjects, and that on account of the extension of the tramlines the residents were more scattered than formerly, and as they had more difficulty in attending the meetings they refrained from joining the Society. He suggested that perhaps it might be more convenient for members to meet in the afternoon instead of in the evening.

The President thought that if, in addition to the monthly meetings, they annually held a reception and a conversazione and gave courses of lectures as well as an annual dinner, the Society would greatly benefit, and its objects would be largely promoted. The President referred at length to the Intercolonial Catalogue of Scientific Literature. This work, he said, would annually fill 17 vols., and would contain from 160,000 to 200,000 entries yearly, and would prove an inestimable boon, as it would relieve scientific people from much of the trouble now attendant upon hunting up references to scientific subjects. He trusted that some effort would be made to collect and forward material from Australia for inclusion in this catalogue. He was also strongly in favour of a federation of the leading Scientific Societies in Australia, and the establishment of a national Australian Academy, and suggested that a site for such an academy, museums, art galleries, and a Federal University, and other Scientific and Educational Societies might be reserved in the capital of the Commonwealth. The organisation proposed would somewhat resemble the Continental academies so far as its scope was concerned, but under rules more like those of the Royal Society of London. If the proposal were carried out it would be of great benefit to Australia not only in its general usefulness, but in the stimulus it would give to the younger Scientific men, since election to it, would depend upon fitness and merit. It would be very gratifying to all who were interested in the matter if with the new century and the inauguration of the Commonwealth there was increased attention paid to the question of instruction in Science in the schools, and better provision made in this direction,

for it would be of great usefulness in training the power of observation of the children, and teaching them to think about what they saw and heard. Some of the teaching now done at the University should be given in the schools, and the student would then gain valuable time at the University for things he could not do at school. He did not advocate the teaching of technical or applied Sciences in ordinary schools. It was to be regretted that the Sydney University was probably the only modern University that excluded Science from its entrance examinations. Professor Liversidge made also some observation in connection with the advantages of a metric system of weights and measures, and a decimal system of coinage. He strongly recommended that its teaching should be compulsory in all the schools of the State. The chief defect of our present system of weights and measures was that there was no simple connection between measures of length, weight, and capacity. Investigation showed that in countries where the change to the metric system had been made, no great difficulty was experienced, and an increase of trade had resulted.

He strongly urged that increased attention should be paid to commercial education and suggested that not only should it include a certain amount of instruction in Science, but that the standard for the higher branches should be as high as for any of the learned professions, also that part of the course should be given at the University.

A vote of thanks was passed to the retiring President, and Mr. H. C. Russell, B.A., C.M.G., F.R.S., was installed as President for the ensuing year.

Mr. Russell thanked the members for the honour conferred upon him.

ABSTRACT OF PROCEEDINGS, JUNE 5, 1901.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, June 5th, 1901.

G. H. Knibbs, F.R.A.S., in the Chair.

Thirty-two members and three visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of four candidates were read for the second time.

Sixty-three volumes, 306 Parts, 13 Reports, 89 Pamphlets, two Maps, one Physical Atlas and one Hydrographic Atlas, total 475, received as donations since the last meeting, were laid upon the table and acknowledged.

The Chairman announced that a series of fourteen stereoscopic slides of the relics of Sir John Franklin's Expedition, brought home in the "*Fox*," by Captain McClintock, in September 1859, had been presented to the Society by Mr. John Plummer, and were placed on the table for inspection.

The following illuminated address was also exhibited :—

"Royal Society of New South Wales.

To The King's Most Excellent Majesty: King Edward VII.

May it please your Majesty,

We your Majesty's most dutiful and loyal subjects, the President, Council, and Members of the Royal Society of New South Wales, at this our first meeting since the lamented death of our beloved and revered Sovereign, Her Gracious Majesty Queen Victoria, most respectfully beg leave (in confirmation of our President's telegraphic message sent in January last) to offer to your Majesty and to the members of the Royal Family, an expression of our heartfelt sympathy in the great bereavement which your Majesty, the Royal Family, and the Empire have sustained.

We feel that we have a more than ordinary claim to this sad privilege, inasmuch as the title of our Society was granted to us by Her late Most Gracious Majesty.

We also desire respectfully to offer to your Majesty, our loyal congratulations upon your accession to the Throne, and our cordial wishes that your Majesty's Reign may be long, happy, and prosperous : also that it may be characterised, like that of Her late Majesty, by marked progress

in the advancement of Science, Literature, and Art, and in the amelioration of the condition of the people.

Signed on behalf of the Royal Society of New South Wales,

A. LIVERSIDGE, PRESIDENT.

GEO. H. KNIBBS } HON. SECRETARIES.
J. H. MAIDEN... }

Sydney, 1st May, 1901."

THE FOLLOWING PAPERS WERE READ:—

1. "On a new rock allied to nepheline phonolite, from Kosciusko, N. S. Wales," by F. B. GUTHRIE, F.C.S., Prof. DAVID, B.A., F.G.S., F.R.S., and W. G. WOOLNOUGH, B.Sc.. F.G.S.

The rock described in this paper was discovered by two of the authors in company with Mr. Richard Helms last January. It occurs in the form of a dyke, seven feet wide, with vertical walls, trending in an east and west direction, where it crosses "Evidence Valley" (Helms) (the Valley of the Blue Lake, Kosciusko) at a quarter of a mile above the junction of "Evidence Valley Creek," with the Snowy River. The dyke is strongly intrusive into the typical gneissic granite of the Kosciusko Plateau, and is perhaps, of early Tertiary or Cretaceo-Tertiary age, like the soda-trachytes of the Glass-House Mountains, Queensland, the Warrumble Mountains, and the Gib Rock, N. S. Wales, and allied rocks described by Professor Gregory as occurring at Mount Macedon in Victoria. The Kosciusko rock is characterised by its large proportion of nepheline which dominates all the other minerals. The nepheline occurs in micro-porphyritic idiomorphic crystals. The soda-augite ægirine is also abundant, and there is a small amount of glassy material in the base through which are scattered delicate acicular crystals and microlites of felspar. A few small amygdules may be noticed, not sharply marked off from the surrounding rock; they consist of a shell formed chiefly of analcime enclosing secondary calcite. The specific gravity of the rock varies from 2·43 – 2·5. The chemical composition of this remarkable rock has been determined by Mr. Guthrie to be as follows:—

Water at 100° C. =	0·23	SiO_2	= 52·40
Water above 100° C. =	2·89	Al_2O_3	= 19·93

Fe_2O_3	= 3·83	Cl	= 0·24
FeO	= 1·51	CO_2	= 0·60
CaO	= 1·34	P_2O_5	= trace
MgO	= 0·32		——
K_2O	= 4·10		99·75
Na_2O	= 11·71	Deduct O equiv. for Cl	0·05
MnO	= 0·45		——
SO_3	= none		99·70

The Kosciusko rock differs conspicuously from typical phonolites in the following respects :—(1) low silica percentage; (2) entire absence of phenocrysts of sanidine. It is obviously a felspathoid rock, and although its silica percentage allies it with the basalts, its mineral constitution, chemical composition and low specific gravity link it with the phonolites. As far as the authors are aware, it is unlike any rock that has hitherto been described from any part of the world.

2. "Preliminary notes on the intermediary host of *Filaria immitis*, Leidy," by THOS. L. BANCROFT, M.B. *Edin.*

Filaria immitis, a worm-parasite of the dog, common throughout the world, but more especially in the warmer parts, of from five to ten inches in length; the male being the smaller, is found generally in the right ventricle of the heart, and in the pulmonary artery. The so-called embryos, $\frac{1}{90}$ in. × $\frac{1}{3500}$ in., are produced in great numbers; the late Dr. Spencer Cobbold taught that an intermediary host was necessary to transmit the parasite from one dog to another. Among others, Grassi, Sonsino, and J. Bancroft endeavoured to discover this intermediary host. The dog-flea (*Pulex serraticeps*), the various dog lice, and ticks were examined but with negative results. The writer for thirteen years past had endeavoured to find the intermediary host, examining *Pulex serraticeps;* the common horse-fly, *Stomoxys sp.?; Culex vigilax*, Skuse—a day-flying mosquito; the intestinal worm parasite of the dog—the *Anchylostoma* or *Dochmius trigonocephalus*. The possibility of metamorphosis being essential seemed doubtful, the embryo might, it was thought, go through a cold stage for several days in

the body of an insect and then develope, after introduction into the body of the dog. A puppy, who ate 110 *Stomoxys* flies gorged with filariated blood, in one month shewed after a series of experiments, extending over nearly a year, that such an hypothesis was untenable; and moreover, that the time taken by the young filaria to arrive at sexual maturity was not less than seven months nor more than twelve. After discussing Grassi's discovery of the intermediary host of *Filaria immitis*, viz., the *Anopheles maculipennis*, Meigen, syn. *A. claviger*, Fab., and the statements of a paper by Grassi and Noè on 'the propagation of the filariæ of the blood exclusively by means of the puncture of peculiar mosquitos,' the author states we are now able to give an exact account of the life-history of both *Filaria nocturna*, and *F. immitis*. The sexually mature worms in man or dog, produce embryos, which swim in the blood: the mosquito on biting abstracts some of the embryos, these develop in the mosquito's body, and in about three weeks are capable of entering their final or definitive hosts, passing into the puncture made by the mosquito in the skin; they then advance to sexual maturity in the course of about a year. The position in the mosquito's body during the metamorphosis of the embryos distinguishes *F. nocturna* from *F. immitis*, the former being in the thoracic muscles, the latter in the malphighian tubes, at their maximum development: the later are distinguished as being shorter and thicker. It has been learnt that mosquitos live for long periods and not merely a few days as was formerly supposed, and that during their life they bite frequently. In Europe, *Anopheles maculipennis* plays the rôle of host for the malarial parasite, for *F. immitis* and it is believed also for *F. nocturna:* in Australia the house-mosquito, *Culex skusii*, Giles, is host for both *F. nocturna* and *F. immitis*, and probably also for the malarial parasite.

3. "Two historical notes in regard to Captain Cook the Circumnavigator," by J. H. Maiden, Government Botanist and Director of the Botanic Gardens, Sydney.

Students of Australian history will remember that as regards the death of Captain Cook, besides stabbing him with a dagger,

the natives of Hawaii on that memorable 14th of February, 1779, stunned him with a club. Mr. Maiden, on his recent visit to England, saw at Shrigley Hall near Macclesfield, a club stated to be the identical one by which Captain Cook met his death. He shewed photographs of the club and of its label. The club was given by Admiral John Hunter (a Governor of New South Wales) to Thomas Leigh Esquire, of Lyme Hall, and a brief account of the same was furnished by Sir Joseph Banks. It is about three feet long and of ironwood. The club has been at Lyme Hall and Shrigley Hall (within five miles of each other) for nearly a century and there is no reason to doubt its authenticity. Mr. Maiden also exhibited copies of a mural tablet and of a gravestone in the middle aisle of the church of St. Andrew the Great, Cambridge, to commemorate the family of the great circumnavigator, three members of which are buried in the church. The existence of these monuments appears to be scarcely known in Australia.

ABSTRACT OF PROCEEDINGS, JULY 3, 1901.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, July 3rd, 1901.

HENRY DEANE, M.A., M. Inst. C.E., in the Chair.

Fifty-five members and thirteen visitors were present.

The minutes of the preceding meeting were read and confirmed.

Messrs. W. A. Dixon and J. Palmer were appointed Scrutineers, and Mr. F. B. Guthrie deputed to preside at the Ballot Box.

The certificates of four candidates were read for the third time, and of three for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

Hamilton, John William, Civil Engineer; 'Herrickville,' Alt-street, Ashfield.

Kidd, Hector, Civil and Mechanical Engineer; 15 Mansfield-street, Glebe Point.

Purvis, John G. Stockoe; Chief Draftsman, Board of Water Supply and Sewerage, 341 Pitt-street.

Süssmilch, Carl Adolph, Assistant Teacher of Geology and Mineralogy, Sydney Technical College; 143 Forbes-st.

When recently in England, Mr. J. H. Maiden, one of the Honorary Secretaries, heard that the distinguished Australian Explorer, Mr. E. J. Eyre, was still alive. As he was unable to call upon Mr. Eyre, he wrote unofficially to that gentleman wishing him every good wish, and asking that he might be favoured with a photograph to take back to Australia. Following is Mr. Eyre's reply:—

[Copy.]

Walreddon Manor, Tavistock, Devon,
2nd Oct., 1900.

Dear Sir,—I am obliged by your letter of 29th September and for the good opinion you are pleased to express of my Australian travels.

I am sorry I cannot send you a photograph, not having one, for I have not been photographed for more than 30 years, and at my time of life (now in my 86th year) am never likely to be photographed again.

Yours faithfully,
EDWD. JOHN EYRE.

J. H. Maiden, Esq.

At the monthly meeting of June 5th, Mr. Maiden informally brought the matter before the members, who were very pleased to hear of the veteran's welfare.

Professor David moved, Mr. Maiden seconded and unanimously carried, "that the good wishes of the Royal Society of New South Wales be conveyed to Edward John Eyre, the intrepid Australian Explorer, coupled with the hope that he may yet enjoy many happy years of life."

The hope was also expressed that he might be persuaded to have his photograph taken which would find an honoured place on the Society's walls.

The meeting then resolved itself into a 'Reception' or informal Conversazione and Smoke evening.

THE FOLLOWING EXHIBITS WERE SHEWN :—

DAVID, Prof. T. W. E., B.A., F.R.S.—Glacially striated block of quartzite from near Hedley Tarn ; ditto from "Helms" Moraine; ditto from Moraine near Lake Merewether, Kosciusko. Small piece of glaciated pavement of quartzite Snowy River, Kosciusko. Smoothed and scratched boulders from Moraines, Kosciusko. Photographs illustrative of glacial action at Mount Kosciusko. Thin sections of Radiolaria and Diatoms from the Lower Cretaceous Rocks, Maranoa, Queensland. Thin sections of Phonolitic nephelinite, Mount Kosciusko. Shewn under the microscope. Radiolarian shells from Barbadoes.

DEANE, H., M.A., M. Inst. C.E.—Drawings of proposed Railway Station, Devonshire-street and Belmore Road. Drawings of proposed Car House, Fort Macquarie, Sydney. Lithographs for the proposed Sydney Harbour Bridge.

FLASHMAN, J. F., M.D.—Microscope slides—Sections of spinal cord stained with methylene blue (Nissl's method) and showing the Nissl bodies. Sections of cerebral cortex stained by Cox's modification of Golgi's process, showing the cells and their processes, especially the moniliform or bud-like processes.

GRIMSHAW, J. W., M. Inst. C.E.—Fossil jaw bone and teeth of extinct animal from the River Murray.

GUTHRIE, F.B., F.C.S.—Apparatus for determining the quality of flour—Entomological.

HARGRAVE, LAWRENCE—Flash Boiler for Flying Machine, and tool for making same.

LIVERSIDGE, Professor, M.A., LL.D., F.R.S.—Metric system—ordinary weights and fluid measures used in commerce. Imitation silk. Photograph, sovereign etched by chlorine 5 dias., obverse

and reverse sides. Quartz shewing incrustation in progress of original crystals. Silver—siderite and calcite. Native silver—antimony, calcite, siderite. Native silver in altered rock. Native silver from a nugget of 32 lbs, probably solid. Amphibolite, bore cores. Calcite, crystals of Dyscrasite. Cinnabar, Sromeyerite, Siderite, changing to Limonite. Crystals of Willyamite. Dyscrasite crystals. Dyscrasite with splash of Pyrargite, Lode matrix. Galena with siderite. Galena with calcite and siderite. Niccolite etc. Pyrargyrite, calcite and siderite. Schist bore cores. Smaltite, Niccolite, Siderite. Smaltite shewing Siderite and Calcite, matrix. Stalactite from well water, Olive Downs. Stephanite crystals. Photographs (23) of the Mining School, University of Sydney.

Maiden, J. H., Director of the Botanic Gardens—An early addition of Gerarde's celebrated Herbal (1636). Australian Seaweeds collected and named by Professor W. H. Harvey of Dublin in 1856 to illustrate his celebrated work *Phycologia australasica* (one of six vols.) Botany of Captain Cook's First Voyage 1768 - 1771. The copper plates engraved 1772 - 1779 but not published until 1900 [Lent by the Director of the Botanic Gardens]. Elive's Monograph of the genus Lilium. Hooker's Rhododendrons. Roscoe's Monandrian Plants. Letter dated 1789 from Sir J. E. Smith, Botanist, the owner of the Linnean Herbarium and describer of many of the earliest Port Jackson plants. Photographs—(1) Paddy "field" Ceylon; (2) Ditto, The Harvest; (3) Ditto, On the sides of steep hills: shewing the way in which the experience of centuries is brought to bear in so arranging the patches that they may oppose least resistance to heavy rains.

Pittman, E. F., A.R.S.M., Government Geologist—Enlarged Photographs (14) framed, chiefly Australian Rocks and views in the far West.

Quaife, F.H., M.A., M.D.—Spectroscopic apparatus.

Royal Society of New South Wales—Photographs (framed) of illuminated addresses to Her late Majesty Queen Victoria and His present Majesty King Edward VII.

RUSSELL, H. C., B.A., C.M.G., F.R.S., and LENEHAN, H. A., F.R.A.S. —Lick Observatory, photographs of the Moon (19). French enlarged photographs of the Moon (3 Portfolios). Photographs of Stars (3) framed.

STUART, Professor T. P. ANDERSON, M.D., LL.D.—Plaster cast of the Head of 'Jimmy Governor,' one of the Breelong Blacks hanged for murder at Darlinghurst. Dilatation of Pelvis of Kidney due to impacted calculi numbering 5923. (In formalin solution).

TIDSWELL, Dr. FRANK, D.P.H.—Apparatus: (1) Soxhlet's milk steriliser; (2) Roger's milk steriliser; (3) Mulford's formalin regenerator. Specimens of milk kept for various number of years.

WARREN, Professor, M. Inst. C.E., Wh. Sc.—Optical Torsion testing apparatus. Pressure-gauge testing apparatus. New Zeiss stereoscopic Microscope with double objective and independently adjustable eye-pieces, both for focus and distance between the eyes. To shew performance of microscope, a microscopic slide, viz. lung of toad.

WALSH, HENRY DEANE, M. Inst. C.E.—Facsimiles of National Manuscripts (4 vols.)

WOOLNOUGH, W. G., B.A., F.G.S.—Augite-Andesite, Hornblende-Andesite, Hornblendic-Granite, Rocks and Fossils, from Fiji.

ABSTRACT OF PROCEEDINGS, AUGUST 7, 1901.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, August 7th, 1901.

Professor T. W. EDGEWORTH DAVID, B.A., F.R.S., V.P., etc., in the Chair.

Thirty members were present.

The minutes of the preceding meeting were read and confirmed.

An apology for non-attendance through illness was received from the President Mr. H. C. RUSSELL.

Mr. ROBERT LITTLE enrolled his name and was introduced.

The certificates of three candidates were read for the second time, and of six for the first time.

Thirty-five Volumes, 318 Parts, 22 Reports, 16 Pamphlets, and 4 Hydrographic Charts, total 405, received as donations during June and July were laid upon the table and acknowledged.

The Chairman announced that copies of the Society's Journal, Vol. XXXIV. for 1900, were ready for delivery and could be had by members on application to the Assistant Secretary.

Also that the Fourth Science Lecture 1901, on "The practical application of Economic Theories, with special reference to the theory of value and laissez-faire," by The Hon. B. R. WISE, K.C., M.L.C., Attorney General and Minister for Justice, N.S. Wales, would be delivered in the Royal Society's House, on Thursday, the 29th August, 1901, at 8 p.m.

THE FOLLOWING PAPERS WERE READ:—

1. "Notes on some analyses of air from Coal Mines," by A. A. ATKINSON, Chief Inspector of Collieries and F. B. GUTHRIE, F.C.S., F.I.C.

The authors gave the analyses of several samples of air from the return air-ways at Wallsend and Burwood Collieries, and of

gases produced by fires in the Gunnedah and Greta Collieries, the latter was an old gob. fire. The analyses were as follows:—

Return Air-Way, Wallsend Colliery—

	Oxygen	CO_2	N.	Deficiency of O.	Excess of CO_2
1.	20·03	0·19	79·78	0·85	0·16
2.	19·32	0·27	80·41	1·55	0·24
3.	19·28	0·31	80·41	1·59	0·28
4.	20·03	0·24	79.73	0·85	0·21

Air from holings Burwood Colliery—

	Oxygen	CO_2	N.	Deficiency of O.	Excess of CO_2
1.	20·42	0·08	79·50	0·48	0·06
2.	20·77	0·04	79·19	0·13	0·01
3.	20·83	...	...	0·07	...
4.	20·34	0·13	79·53	0·56	0·10

Air from sealing, Gunnedah Colliery—

	Oxygen	CO_2	N.
1	15·88	1·46	82·66
2	16·93	1·04	82·03
3	13·68	2·09	84·23
4	15·79	1·45	82·76

From old gob. fire, Greta Colliery—

	Oxygen	CO_2	N.
1	10·50	2·14	87·36
2	10·60	2·17	87·23

The authors described the conditions as to temperature and air-current, etc., under which the samples were taken, and their bearing on the subject of the ventilation of coal mines. The analyses were compared with published analyses of air in the return-ways of English collieries made by Dr. Haldane, and the question of the effects of diminution of oxygen, presence of carbonic acid, black-damp and other injurious gases found in the air of coal-mines, discussed in relation to their action on men and lights. A discussion followed in which several members took part.

2. "Symmetrically distorted crystals of Cassiterite from Western Australia," by W. G. WOOLNOUGH, B.Sc., F.G.S.

The crystals were collected at Cooglegong, Pilbarra, W.A. by Mr. B. F. Davies, B.Sc., (London), who kindly allowed them to be

described. They occur in a coarse pegmatite vein. The remarkable feature in them is the fact that instead of being modified tetragonal pyramids with all their faces equally developed, they have undergone a symmetrical distortion. In some cases this distortion has produced pseudomonoclinic crystals, in other cases pseudorhombic. Measurements of the interfacial angles proved, however, that the crystals are really tetragonal. A pseudorhombic modification of rutile is described in Dana's "System of Mineralogy," (6th Edition) but no such modification of cassiterite is described. The pseudomonoclinic distortion is believed to be quite new. The amount of material available was insufficient for chemical analysis, but blowpipe tests proved that it must be almost pure tin oxide. Stereographic projections and figures of the crystals are given.

EXHIBITS.

The following specimens were shewn by Mr. E. F. PITTMAN, A.R.S.M.:—Four specimens, Ruby Hill, Bingara—(1) breccia containing lumps of eclogite; (2) eclogite consisting essentially of garnet, diopside and bytownite felspar, this occurs as boulders in the breccia; (3) basalt containing eclogite, garnet etc., occurs as a dyke cutting through the breccia-pipe; (4) piece of basalt cut to show an inclusion of garnet (pyrope) with a ring of kelyphite. Quartzite traversed by veins of, and impregnated with precious opal; White Cliffs Opal Fields. "Niggerheads," siliceous concretions round a nucleus of wood; White Cliffs Opal Field. Precious opal, Ballina District; this is found occupying cavities in basalt. Green common opal, fifteen miles from Port Macquarie. Specimens from the Peaks Mine, Burragorang—(1) quartz with native silver, argentite and copper pyrites; (2) native silver with galena, mispickel and copper pyrites; the galena carries 170 ozs silver per ton; (3) fine-grained galena assaying from 600 to 800 ozs. per ton. (4) pyrargyrite on quartz. Cosalite (sulphide of bismuth, lead and silver), Duckmaloi Creek, Oberon District. Native bismuth, Pheasant Creek, fifty miles east of Glen Innes, Gahnite (zinc spinel) with galena, nine miles west Broken Hill. Rœpperite

(silicate of manganese, zinc and iron) with galena and rhodonite, Block 14 Broken Hill. Lode tin ore, Buddigower, West Wyalong. Quartz with arsenical pyrites assaying on an average two per cent. of tin, Buddigower. Cassiterite containing 73·5 per cent. metallic tin, Buddigower. Specimens from Chillagoe, North Queensland—Magnetite crystallising in rhombic dodecahedra; Chrysocolla pseudomorphous after azurite. Cyanite with mica schist, Alma Prospecting Claim, five miles from Broken Hill. Crocoisite, Zeehan, Tasmania. A large block specimen showing a complete section across a vein of silver ore and the successive deposition of the constituent minerals in layers parallel to the walls. Gangue, quartz and chalybite ore, native silver, galena, mispickel, blende, Yerranderie Silver Mine, Burragorang.

ABSTRACT OF PROCEEDINGS, SEPTEMBER 4, 1901.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, September 4th, 1901.

H. C. RUSSELL, B.A., C.M.G., F.R.S., President, in the Chair.

Forty members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

An apology for non-attendance through illness was received from Mr. J. H. MAIDEN, one of the Hon. Secretaries.

Mr. C. A. Süssmilch enrolled his name and was introduced.

Messrs. J. W. Grimshaw and R. T. Baker were appointed Scrutineers, and Mr. W. M. Hamlet deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

Holt, Thomas Samuel, 'Wynterdyne,' Burwood.
Peake, Algernon, 25 Prospect Road, Ashfield.
Pollitt, James Chas. Tomlin, 'Athole,' Croydon.

The certificates of three candidates were read for the third time, of six for the second time, and of three for the first time.

Thirty-nine Volumes, 117 Parts, 9 Reports, 35 Pamphlets and 2 Geological Photographs, total 202, received as donations since the last meeting, were laid upon the table and acknowledged.

The Chairman announced that the Fifth Science Lecture 1901, on "The History of a Grain of Wheat," by F. B. GUTHRIE, F.I.C., F.C.S., would be delivered in the Royal Society's House, on Thursday, October 24, 1901 at 8 p.m.

THE FOLLOWING PAPERS WERE READ:—

1. "Recurrence of Rain—the relation between the Moon's motion in declination and the quantity of rain in New South Wales," by H. C. RUSSELL, B.A., C.M.G., F.R.S.

The paper was essentially a continuation of that on the "Periodicity of good and bad seasons," read 3rd June 1896. The author stated that while coastal rains were irregular, those of the interior shewed a 19-year periodicity. Regretting that observations did not extend over a more lengthy period, it was pointed out that some rain records of Horsham, Victoria, dating back to 1848 were valuable, our first record at Bathurst beginning in 1858. To minimise possible errors, the averages of neighbouring stations were taken. An illustrative diagram accompanied the paper, the author stating that between 1850 and 1851, 1869 and 1870, and 1888 and 1889, the thick vertical lines—19 years apart—divided the records in 'natural spaces' in which the first six years had abundance of rain, and the remainder was a 'dry period.' The first bad year of the series, we were stated to be now in, was 1895, the loss of sheep from starvation between 1895 and 1900 being alleged to be 25,000,000, not including the loss of 20,000,000 natural increase. The diagram shewed also the curve of extreme southerly declination of the moon for each year. The author in

conclusion, states that rain is shewn for three periods of nearly 19 years each, 'to come in times of abundance when the moon is in certain degrees of her motion south, and when the moon begins to go north, the droughty conditions prevail for 7 or 8 years,' which he said is 'either a marvellous coincidence, or it is a law connecting the two phenomena,' and he is convinced that there is some connection between the two.

2. "The theory of City Design," by G. H. Knibbs, F.R.A.S.

The duty of designing and setting out an important city (the Federal Capital), is one which, in the near future and in the ordinary course of things, will be cast upon the Commonwealth of Australia. An elaboration of the principles which should govern the design of such a city, and a statement of the several matters which call for systematic consideration in connection therewith was undertaken by the author, pointing out that a capital city, its general design, its utilitarian and æsthetic features, constitute and enduring monument of the intelligence and foresight, the nobility of the sentiment, and the dignity of the artistic idea of the people creating it; that in order to prevent poverty of conception, or present limitations, so operating as to make it forever impossible to create a beautiful city, it is absolutely necessary that the requirements and probable developments of the far-distant future should be fully considered and liberally provided for in the design.

The subject was then systematically treated under the following headings:—1. Introductory. 2. General idea of a city. 3. Radial street-system. 4. Position of radial centres. 5. Combination of radial and rectangular street-systems. 6. Curved streets. 7. Cardinal direction of rectangular streets. 8. Width of streets. 9. Localisation of the various types of street. 10. Grade and cross-section of streets. 11. Engineering features of streets. 12. Size of blocks between streets. 13. Height of buildings. 14. Theory of aspect. 15. The æsthetics of design. 16. Sites for monumental buildings and monuments. 17. Treatment of streets from the standpoint of æsthetics. 18. Public

parks and gardens. 19. Hygienic elements of design. 20. The preliminaries of design. 21. Conclusion.

After shewing geometrically that the radial system, especially the hexagonal form of it, possessed great advantages in reducing the distance of travel; that the *rectangular system* of roads and streets so much in vogue in the States of Australia, is *inconsistent* with what may be properly called, not merely the natural position, but also the *position of maximum efficiency;* the author went on to discuss the question of the proper position for the centres from which the main radiating lines of street should diverge, and which should be united by those lines of street which constitute the main arteries of traffic.

As typical examples of centres, the Capitol and White House at Washington, the Arc de Triomphe between the Avenue de la Grand Armée and the Avenue des Champs Elysées were cited. The position of the centres and the main streets, were said to be dependent, partly on the topographical limitations of the site, partly on the position of outlying centres and the existing or potential roads and railways thereto, and partly also upon the suitableness of certain localities within the site for the special purposes or activities, for which provision must be made; and their selection required not only a comprehensive view of the administrative, educational, industrial, residential, military and other needs of a capital city, not only a due regard for its communication with the outer world and for all the contingencies both in times of peace and war, which that communication involves, it required also a nice appreciation of the topographical adaptabilities of the site, so that in the design the interdependence and mutual influence of every element shall be fully estimated and the general arrangement made the most convenient possible, and therefore the most economical. Further the arrangement should allow of that expansion which the future will certainly require.

The introduction of curved streets to alleviate gradients and enhance artistic effects, the use of what have been called ring streets, as at Karlsruhe, and the best cardinal directions for

rectangular streets, were fully discussed. In connection with this last feature the theory of solar shadows was treated, and a diagram, giving their position at any hour of the day and month in the year, was exhibited.

The considerations which should regulate the width of streets were sketched, and it was shewn that the interdependence of the types of occupation and of street, of settlement and of traffic, and the tendency of each to perpetuate itself without regard to the welfare of the city as a whole, involved more than ordinary care in the arrangements of any city that is intended to be ideally beautiful, and that no effort was wasted which has for its object the conservation of the higher interests in such a way as to involve a minimum of alteration with its attendant expense and difficulty.

In treating of the grade, cross-section, and engineering features of streets, it was stated that if the positions for the mains, conduits, tunnels, etc., required for water, gas, electric, or various forms of power-supply, for sewerage systems, for telephone and telegraphic services, or for underground communication of any sort, were thoroughly considered at the outset, they could be so located as to involve the minimum disturbance of traffic, and the least expense for maintenance and repair; and the characteristic breaking up of, and injury to well-constructed streets, in order to reach such mains and conduits, would then become an unknown element. Certain suggestions were made as to the sizes of blocks, and height of buildings, and the elements of the theory of aspect were indicated.

Touching the æsthetics of design it was said that a study of those examples of architecture which impress the human consciousness with a sense of beauty, has revealed the fact that their general proportions, and the mutual relationship of their details, conform to simple numerical ratios and to an harmonious scheme. Certain geometrical forms constituted, as it were, a skeleton on which architectural features were developed, in symmetrical grouping, with, however, such relief in detail as to obviate too cold and severe an effect, or what may, perhaps, be called an

appearance of excessive symmetry. The proper subordination in the various parts of structures of their mass effects was necessary to awaken that impression of stability and repose which, together with grandeur of form and beauty of outline, and the grace of harmonious ornament, constitute the ideal of architectural design. Although these matters required the immediate and intense attention rather of those charged with erecting the buildings of a city, than of those whose function it is to design its streets and general arrangements, the latter can by no means neglect them. A knowledge of and attention to æsthetic laws are absolutely necessary in studying a design, so that the artistic possibilities of every feature could be exhausted.

The nature of advantageous sites for effect, the importance of appropriating them for those great public buildings and monuments upon which a people may be expected to lavish its wealth and artistically express its national feeling, the spatial provision necessary for the proper view of such buildings and monuments, the general treatment of streets from the standpoint of æsthetics were discussed at some length. It was said that even alteration of width was preferable to excessive symmetry; that the undisguised presence of telegraph wires, telephone cables, etc., besides being unsightly, was a menace to public safety in cases of fire; that though overhead electric wires in a tram-system were less unsightly, yet they were inconsistent with a fine effect, and might well be transferred to underground conduits, as has already been done in some instances. Monuments and masses of foliage could be employed as a relief to street uniformity, and to obviate the ugly effect which arises from the disappearance of buildings etc., over the summit of streets crossing a ridge.

Touching parks and gardens, which were not only an ornament to a city but a necessity to its people, if their health is to be regarded, we were justified in making liberal provision; irregular surfaces being preferred, as giving the landscape gardener greater scope for displaying his art, and as possessing intrinsically greater charm.

In sketching the hygienic features to be considered in design, it was, among other things. urged that there should be ample provision for play or recreation grounds in connection with every school, college, or other educational establishment, and a complete abandonment of the present niggardly notion of what is a reasonable provision in this respect. That the recreation of a people should be under pleasant and healthy conditions is always important, and never more so than in the case of the young, so that the school-grounds of a beautiful city should in themselves be a source of attraction, and exhilarant in their reaction upon those who use them; and similarly hospitals and sanitoria should have bright surroundings and pleasant aspects, for the cheery and tonic effect of these is by no means the least potent of the remedies available to those charged with the care of our health.

The great importance of thoroughness in the matter of initial preparation by a complete topographical and contour survey, representing the surface, and furnishing the necessary geological information was referred to. The time lost in making this is gained in the end, and it is only by such systematic procedure that satisfactory results can be achieved. Those who have not thoroughly studied this question, are under the impression that what is called the common sense of well educated people is sufficient for the task of designing, but that is not the opinion of those who have seriously given the matter their professional attention. If evidence was wanted of the calamity of indifferent design, it is to be had in Sydney and its suburbs. The topographical features of Sydney would have permitted it to be, if not the most, at least one of the most beautiful cities of the world. No word-painting could too vividly, or with too high a colour, express the magnificent opportunity that once existed for the people of this land to create a city of almost unparalleled beauty: that opportunity has been destroyed through the ignorance, and want of apperception of those whose duty it was to avail themselves of it, and while doing so to have left also a monument of the dignity of their ideas. And

the reason of failure is that no great scheme for the creation of the city was ever heartily entertained.

Given a complete abandonment of the present practice of lightly regarding the matter of city design, and a really exhaustive study from every possible point of view of any selected site, we have a reasonable prospect of noble and far-seeing designs, and the future cities of the Commonwealth will bid fair to be all that we could wish, so far as the art of city building is concerned. And unique among them, said the author, should be that which will be known as the Capital of Australia.

EXHIBITS.

Aboriginal rock carvings.—Mr. R. H. MATHEWS. L.S., of Parramatta, exhibited five large plates containing a series of photographic copies of aboriginal carvings found on some flat rocks situated on the Burnett River, at the confluence therewith of Pine Creek, Wide Bay district, Queensland. Many of the drawings are scarcely distinguishable owing to long exposure to the weather, and it was found necessary to freshen up the lines with chalk before taking the photographs. The objects are very numerous, and vary in length from a few inches to upwards of two feet, representing native weapons, animals, human foot-marks, and nondescript devices. The mode of execution was to make a row of punctures along the outline of the drawing by repeated blows with sharp-pointed pieces of hard stone; the spaces between these indentations being then chipped out, making a complete groove along the exterior of the drawing. The positions of these punctures are still easily discernable. Mr. Mathews stated that by the courtesy of a friend he succeeded in getting a portion of the rock chiselled out and removed; this block of stone, containing a very distinct carving of a human foot, was exhibited at the meeting.

ABSTRACT OF PROCEEDINGS, SEPTEMBER 26, 1901.

A Conversazione was held in the Great Hall of the University, on Thursday, September 26, at 8 p.m. The Hall and approaches were decorated with ferns, palms, and rare pot plants, generously supplied by Mr. J. H. MAIDEN, F.L.S., Director of the Botanic Gardens; and the former also festooned with flags and banners. The paths to the various Laboratories were lighted with incandescent electric lamps kindly furnished by Mr. W. L. Vernon, Government Architect.

The guests numbered about 600. Unfortunately His Excellency the Lieutenant-Governor, who had notified his intention of being present, was at the last moment prevented by his medical adviser.

His Excellency ADMIRAL BEAUMONT, LADY BEAUMONT, and the officers from the various war vessels in harbour were present.

EXHIBITS.—GREAT HALL.

1. Apparatus.—R. TEECE, Esq., F.I.A, F.F.A. (Australian Mutual Provident Society), Modern calculating machines.

2. Rare books.—H. E. BARFF, Esq., M.A., Registrar and Librarian, University of Sydney, (*a*) Antiquities of Mexico—Edward, Lord Kingsborough, coloured plates, 9 vols., Lond., 1830 - 48; (*b*) Fauna and flora of the Gulf of Naples, published by the Zoological Station at Naples, 1897; (*c*) Lepsius' Egyptian and Ethiopian antiquities, 12 vols., Berlin, 1859; (*d*) Shakespeare illustrations; (*e*) Egyptian Book of the Dead; (*f*) Coptic manuscripts—miracles, etc.

3. From Botanic Gardens.—J. H. MAIDEN, Esq., F.L.S., Director, (*a*) Palms and other decorative plants; (*b*) Freshly cut specimens of flowers of horticultural or botanical interest (names attached).

4. Pictures.—C. A. Benbow, Esq., (*a*) The Edge of the Plains; (*b*) Present and Past, or an Aboriginal's first sight of civilisation.

5. Anthropological instruments, used for measuring the children of New South Wales for the Census 1901.—H. J. W. BRENNAND, Esq., B.A., M.B., (*a*) Anthropometer for measuring the vertical height of persons up to 6 feet 6 inches (2 metres), or of any part of the

body, in centimetres, (designed and made by W. Isaac Masters, Sydney); (*b*) Cephalometric square for measuring the length and breadth of the head in centimetres; (*c*) Dynamometer for registering the strength of the hand grasp; (*d*) Callipers used in Anthropometry, 3; (*e*) Spirometer for measuring the vital breathing capacity of adults and children, in cubic centimetres and inches.

6. Byrne, Elements of Euclid, 1848.—George W. CARD, Esq., A.R.S.M., F.G.S.

7. From Geological Survey Department.—E. F. PITTMAN, Esq., A.R.S.M.. Government Geologist, (*a*) Case of mineral specimens; (*b*) Slide of analcite-basalt under microscope (slide etched and stained to reveal analcite); (*c*) Photographs illustrative of geology and mining in New South Wales.

8. Books.—DAVID CARMENT, Esq., F.I.A., (*a*) The Iliad of Homer, translated by Pope, 1715; (*b*) Annuities upon Lives, by A. De Mowre, 1725; (*c*) Smart's Interest Tables, 1726.

9. Mining.—Prof. T. W. E. DAVID, B.A., F.R.S., (*a*) Specimens of rocks from the Cambrian Glacial beds recently discovered by Mr. Howchin, in South Australia; (*b*) Small meteorite, which struck chimney of cottage at Emmaville, N. S. Wales, May, 1900; (*c*) The new mineral, Sulpho-vanadate of Copper, from near Bivera, South Australia; (*d*) Microscopes and micro-slides; (*e*) Natrolite, from Pokolbin.

10. Stereoscopic slides and stereoscope.—His Honor JUDGE DOCKER, M.A., (*a*) Commonwealth celebrations; (*b*) Blue Mountains.

11. Scientific apparatus, etc.—W. M. HAMLET, Esq., F.C.S, F.I.C., Government Analyst, (*a*) Micro-spectroscope, showing bands of potassium permanganate and eosin solution; (*b*) Polariscope used for finding the quantity of sugar in jams, preserves, etc.; (*c*) Microscope, showing crystals of strychnine chromate; (*d*) Spectroscope, showing bright lines of sodium and thallium; (*e*) Microscope, showing crystals of arsenic.

12. Geodetic and telemetric level.—G. H. KNIBBS, Esq., F.R.A.S.

13. Gold Nuggets, Minerals, etc.—Professor LIVERSIDGE, M.A., LL.D., F.R.S., Professor of Chemistry, (*a*) Sections of silver and copper nuggets, and native copper, showing included silver, from Lake Superior; (*b*) Sections of gold nuggets, including some from Klondyke; (*c*) Photographs of sections of gold and other nuggets; (*d*) Collections of silver minerals from the New Australian Broken Hill Consols Mine; (*e*) Crystallised gold, from solution in ferric chloride.

14. Specimens of native silver from Burragorang.—A. E. MADDOCKS, Esq.

15. Apparatus from Lands Department.—J. W. ALLWORTH, Esq., Chief Surveyor, (*a*) 14-inch theodolite, by Cook and Sons, York, England; (*b*) Heliostat; (*c*) Brunsviga Arithmometer.

16. Public Works Department.—J. DAVIS, Esq., M. Inst. C.E., Under-Secretary, (*a*) Design for North Shore Bridge, 1st premium; (*b*) Design for North Shore Bridge, 2nd premium.

17. Royal Society of New South Wales.—(*a*) Electric movement in air and water, Lord Armstrong, Lond., 1897; (*b*) Supplement thereto; (*c*) Photographs of aboriginals and bora ceremonies.

18. Maps, etc.—T. S. PARROTT, Lieut.-Colonel V.D., (*a*) Large map Transvaal, shewing topographical features, gold-fields, farms, etc.; (*b*) Collection of typical rock and mineral specimens of Transvaal; (*c*) Large number of models of military engineering appliances.

19. Maps.—F. H. QUAIFE, Esq., M.A., M.D., (*a*) Map of Queensland, coast line; (*b*) Watershed of Brisbane River.

20. Scientific apparatus, etc.—H. C. RUSSELL, Esq., B.A., C.M.G., F.R.S., Government Astronomer, (*a*) Harmonograph; (*b*) Photographs of moon and stars; (*c*) New map of Polar regions; (*d*) Interesting books; (*e*) New storm chart of the Atlantic, published in England.

21. Specimen native silver from Burragorang.—A. J. TAYLOR, Esq.

22. Models, etc., from Technological Museum.—R. T. BAKER, Esq., F.L.S, Curator, (a) Models of meteorites; (b) New South Wales marbles; (c) Models of fungi; (d) Models of New South Wales fishes.

23. Old Prayer Books, 1660, 1714.—P. C. TREBECK, Esq., F.R.Met.Soc.

24. Zeiss' Stereoscopic microscope.—Professor W. H. WARREN, Wh. Sc., M. Inst. C.E., Professor of Engineering.

LABORATORIES.

25. Chemical Laboratory.—Prof. LIVERSIDGE, M.A., LL.D., F.R.S., (a) Pieces of apparatus used for various chemical purposes; (b) Spectroscopes showing various emission and absorption spectra; (c) Nernst electric lamp, in which a filament composed of magnesia is used instead of a carbon filament; (d) Plans of some American Mining Schools; (e) The recent additions to the Chemical Department for Metallurgy and Assaying were thrown open for inspection:—These include a building for the crushing, concentrating, and extraction of minerals, an asphalted yard for out-door work, and a new Assay Laboratory; the former building contains a set of stamps (Krupps) presented by Messrs. Noyes Bros., Sydney; Challenge ore feeder, presented by Messrs. Park and Lacey, Sydney; Gate's Rock-breaker; Roger's Rolls; Amalgamating pans; Green's trommels, elevators, samplers; frue vanner; jigs, etc.; a roasting furnace, with a bed 6 × 4 feet; (as far as possible the appliances are of such size as to be conveniently worked by students); also the vats and necessary appliances for the extraction of gold and silver by chlorine, cyanide, and hyposulphite solutions; the new Assay Laboratory is a well ventilated and well lighted building, 55 feet × 41 feet, with a height of 35 feet in the centre, it contains 12 muffle and 20 melting furnaces, together with 32 working benches fitted with draught cupboards, gas, water, and exhaust pumps.

26. Geological and Mining Laboratories.—Prof. T. W. E. DAVID, B.A., F.R.S., (a) Lantern views of Cambrian Glacial beds recently discovered by Mr. Howchin in South Australia, and of the Mt.

Kosciusko Glacial phenomena, in the Lecture Theatre, Geological Department, 9 to 9·20 p.m.; (*b*) "Tyndall Geyser": this working model erupted steam and boiling water at intervals of about twenty minutes, the first eruption was timed for 8·15 p.m.

E. C. ANDREWS, Esq., B.A., Collections illustrating the raised reefs of Fiji.

W. G. WOOLNOUGH, Esq., B.Sc., Collections of the volcanic rocks of Fiji.

27. Engineering Laboratory.—Prof. W. H. WARREN, Wh. Sc., M. Inst. C.E. There was a demonstration of the testing of materials from 9·20 to 9·40 p.m. (*a*) Testing machinery and apparatus, 100 tons, 45 tons; (*b*) Machine for testing materials subjected to alternating stresses; (*c*) Methods of finding deformation of fly-wheel through rotation; (*d*) Method of ascertaining deflection and direct strains on beam; (*e*) Models and instruments.

28. Physical Laboratory.—Prof. J. A. POLLOCK, B.E., B.Sc. The Laboratory was open for inspection. Physical apparatus of various kinds were exhibited. Illustrations shewing principle of new gravity meter.

In the Lecture Theatre, W. M. HAMLET, Esq., F.C.S., F.I.C., exhibited a modern large cylinder phonograph, 8·45 to 9 p.m., on which selections were given to illustrate the improvements in the construction of phonographs.

The following numbers were given on the organ during the course of the evening by Mr. Arnold R. Mote:—1. Grand Offertoire in C. Op. 20, No. 1, *Grison*; 2. Toccata in C., *d'Evry*; 3. Vorspiel (Die Meistersinger), *Wagner*; 4. Overture (William Tell), *Rossini*; 5. Prelude (Act III., Lohengrin), *Wagner*; 6. Grand Offertoire in G. Op. 35, No. 4, *Wely*; 7. Marche d'Hamlet.

ABSTRACT OF PROCEEDINGS, OCTOBER 2, 1901.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, October 2nd, 1901.

H. C. RUSSELL, B.A., C.M.G., F.R.S., President, in the Chair.

Thirty-six members and three visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of six candidates were read for the third time, of three for the second time, and of two for the first time.

Messrs. R. T. Baker and J. L. C. Rae were appointed Scrutineers, and Mr. Henry Deane deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

Birks, Lawrence, B. Sc., F.G.S., 49 Phillip-street.
Card, George William, A.R.S.M., F.G.S., Department of Mines.
Newton, Roland G., "Northleigh," Union-st., North Sydney.
Raymond, Robert Samuel, Leichhardt.
Walton, Robert Hawks, F.C.S., "Flinders," Martin's Avenue, Bondi.
Willmot, Thomas, J.P., Toongabbie.

The following letter was read from Mr. Edward John Eyre the intrepid Australian Explorer, accompanied by his photograph:

[Copy.]

" Walreddon Manor, Tavistock,
England, 26th August, 1901.

Dear Sir,—Your letter dated 10th June last reached me safely. Pray assure the members of the Royal Society of New South Wales of my best thanks for the gratifying expression of their appreciation of my services as an Australian Explorer and for their friendly good wishes which your letter conveys to me.

It is very flattering to me to learn that the Society wishes for my photograph, and I herewith enclose one taken a few days ago just as I completed my 86th year.

For your own cordial good feeling towards me accept my sincere thanks.

Yours very truly,
(Signed) EDWD. JOHN EYRE.

The Honorary Secretary, the Royal Society of N. S. Wales, Sydney."

It was resolved that the photograph be enlarged, framed and hung on the walls of the Society.

The following letter was read from the Private Secretary to His Excellency the Lieutenant Governor :—

[Copy.]

"State Government House,
Sydney, 12th September, 1901.

Sir,—With reference to previous correspondence, I have now the honour to inform you that His Excellency The Lieutenant Governor has received a despatch from the Secretary of State for the Colonies, intimating that the Address from the Royal Society of New South Wales expressing heartfelt sympathy with His Majesty in His late bereavement, and offering loyal congratulations on His accession to the Throne, was duly laid before The King.

2. His Majesty was graciously pleased to command that an expression of His sincere gratitude be conveyed to the President, Council, and Members of the Royal Society of New South Wales for their sympathetic and loyal Address.

I have the honour to be Sir,
Your most obedient servant,
(Signed) H. M. COCKSHOTT,
Private Secretary.

The President, Royal Society of New South Wales."

The President referred to the loss the Society had recently sustained in the death of Dr. H. G. A. Wright, the late Hon. Treasurer of the Society, and it was unanimously resolved that a letter expressing the high appreciation of the life and labours of the deceased on behalf of the Society ever felt by the Council and members generally, be forwarded to Mrs. Wright with an expression of their deep sympathy with her and her family in the irreparable loss they had sustained.

The Chairman announced that the Fifth Science Lecture 1901, on "The History of a Grain of Wheat," by F. B. GUTHRIE, F.I.C., F.C.S., would be delivered in the Royal Society's House, on Thursday, October 24, 1901 at 8 p.m.

Seventeen Volumes, 112 Parts, 14 Reports and 6 Pamphlets, total 149, received as donations since the last meeting, were laid upon the table and acknowledged.

Discussion of Mr. G. H. KNIBBS' paper on "The Theory of City Design." then took place, the following members contributing thereto, viz., Messrs. H. G. McKinney, H. E. Ross, Norman Selfe, J. H. Maiden, His Honour Judge Docker, Professor Warren, Messrs. James Taylor, and Henry Deane. In view of the further business for the meeting Mr. Knibbs but briefly replied.

THE FOLLOWING PAPER WAS READ:—

1. "On the relation between leaf venation and the presence of certain chemical constituents in the oils of the Eucalypts," by R. T. BAKER, F.L.S., Curator, and HENRY G. SMITH, F.C.S., Assistant Curator, Technological Museum, Sydney.

In this paper the authors show that there exists a marked agreement between the venation of Eucalypts leaves and the characteristic constituents in their oils. The venation shown by the leaves of the "Bloodwoods" *E. corymbosa*, *E. trachyphloia*, etc. is indicative of a predominance of pinene in the oils, and an absence of phellandrene. It is this end of the Eucalyptus series that is more closely associated with the Angophoras, because the venation of the leaves is similar, and the chemical constituents in agreement. As the series descends through such species as *E. botryoides*, *E. saligna*, etc., we reach those Eucalypts whose principal oil constituents are pinene and eucalyptol, the latter constituent increasing in amount until such excellent eucalyptol oils as those of *E. globulus*, *E. Smithii*, *E. longifolia*, etc. are reached. The venation of the leaves of these species is similar, is more open, the individual lateral veins have become more distinct, and with the bending of the marginal vein, commencing to form the looping so characteristic of the phellandrene-peppermint group, the species of which include those of *E. dives*, *E. radiata*, *E. amygdalina*, *E. Sieberiana*, etc. The principal constituent in these oils is phellandrene, and at the extreme end this constituent is present in such abundance as to exclude, almost entirely, the eucalyptol, The pinene which was such a prominent constituent in the oils of the earlier members of the series, is only present in the oils of this group in minute quantities. The looping appear-

ance of the venation of the members of the phellandrene-peppermint group has become more open, and the spaces between the principal lateral veins are larger. With the subordination of many of the original lateral veins the spaces provided for the formation of the oil glands is larger, and consequently we find these more numerous in the members of this group; the yield of oil obtainable is therefore much greater, and it is this feature which enables such enormous yields of oil to be obtained from such species as *E amygdalina*, *E. dives*, and *E. radiata*.

ABSTRACT OF PROCEEDINGS, NOVEMBER 6, 1901.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, November 6th, 1901.

H. C. Russell, B.A., C.M.G., F.R.S., President, in the Chair.

Thirty-three members were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of three candidates were read for the third time, of two for the second time, and of three for the first time.

Messrs. R. Greig Smith and T. F. Furber were appointed Scrutineers, and Professor Warren deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

Bartholomew, Charles P., 357 George-street.

McMillan, Robert, 129 Macquarie-street.

Walkom, Archibald John, A.M.I.E.E., etc., Electrical Branch, G.P.O. Sydney.

The President announced that the Council recommended the election of the following gentlemen as Honorary Members of the Society, viz. :—

Professor J. W. Judd, C.B., F.R.S., F.G.S., Royal College of Science, London.

Professor Simon Newcomb, LL.D., Ph D., For. Mem. R.S., Lond. etc. United States Navy, Washington.

Sir Benjamin Baker, K.C.M.G., D.Sc., LL.D., F.R.S., etc., 2 Queen Square Place, London, S.W.

The election was carried unanimously.

Also that the Clarke Memorial Medal for 1901 had been awarded to Mr. Edward John Eyre, the Explorer, Walreddon Manor, Tavistock, England.

Nineteen Volumes, 153 Parts, 6 Reports and 9 Pamphlets, total 187, received as donations since the last meeting were laid upon the table and acknowledged.

THE FOLLOWING PAPERS WERE READ:—

1. "The Thurrawal Language," by R. H. MATHEWS, L.S.

In this paper the author describes the structure of the native speech of the aborigines of the region between Jervis Bay and Port Hacking. An appendix exhibits the elements of some other dialects adjoining the Thurrawal tribes on the north and west, the whole concluding with an extensive Vocabulary.

2. "Note on the sesquiterpene of Eucalyptus oils," by HENRY G. SMITH, F.C.S., Assistant Curator, Technological Museum.

In this paper the author shewed that a sesquiterpene occurs in many Eucalyptus oils, and that it is this constituent that gives the pink colouration to Eucalyptus oil when testing for eucalyptol with phosphoric acid. In the oil of *E. hæmastoma* the sesquiterpene occurs in large amount, over fifty per cent. of the crude oil distilling above 255° C. It is also present in quantity in the oils of several other species. Crystallised chemical products could not be obtained with it by the methods used. It is characterised by a range of five colour reactions which it gives with acids and with bromine

when dissolved in glacial acetic acid. When the vapour of bromine is allowed to fall into the tube containing such a mixture, immediately it touches the liquid a crimson colour is formed, quickly changing to violet and finally to a deep indigo-blue. It boils under atmospheric pressure at 260 – 265° C., has a specific gravity 0·9249 at 19° C., as obtained by repeated fractional distillation finally over sodium. Combustion results gave the terpene formula, and a vapour density determination showed it to be a sesquiterpene. The name *Aromadendrene* has been proposed for it.

3. "Current Papers, No. 6," by H. E. Russell, B.A., C.M.G., F.R.S.

This paper on the drift of current papers shews a gradual increase in the number of those who take a great interest in this experimental work, and also the returned current papers that reached me during the year. In the year November, 1900, to November, 1901, one hundred and thirty current papers were sent to me, and these form the basis of this paper.

In this list there was a marked increase on the tracks Sydney to Canada and United States. Previously very little was known of the drift of bottle papers in that sea; but during this year an appreciable increase of interest has been manifested in the current papers found amongst the islands. These shew very clearly the presence of a very rapid current near the equator, somewhat similar to that in the Indian Ocean. For instance:—Current paper No. 598 made daily a drift near Fiji of 11·1 miles per day; near Gilbert Island, No. 671 travelled at the rate of 19·5 miles per day; and near Phœnix Island the current paper No. 674 travelled 16·8 miles per day; and so on.

The question whether or no certain months of the year deposited most current papers is an interesting one. At first it seemed that current papers aggregate in certain months, but upon the monthly papers which have been received in five years there is not much to support the idea. For instance, the record of the five years is that the greatest number of papers are found in the following months:—March, 1901; May, 1897; October, 1899; and December, 1898. Hence it would be fair to assume that with more

records the greatest number of current papers would appear in every month of the year. But there is good reason to believe that the current paper is affected by the wind as well as the currents, and that strong persistent winds alter the landing places of current papers.

ABSTRACT OF PROCEEDINGS, DECEMBER 4, 1901.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, December 4th, 1901.

Prof. T. W. E. DAVID, B.A., F.R.S., Vice-President, in the Chair.

Apologies for non-attendance were received from the President (Mr. H. C. RUSSELL) and Mr. CHARLES MOORE.

Forty-two members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

Four new members enrolled their names and were introduced.

The Chairman referred to the death of Mr. EDWARD JOHN EYRE the Explorer, to whom the Clarke Memorial Medal had been awarded by the Council on the 30th October last.

The Chairman announced that the Council had appointed Mr. DAVID CARMENT, F.I.A., F.F.A., as Honorary Treasurer, in the room of the late Dr. H. G. A. WRIGHT, who had held the office for thirteen years. The appointment met with the cordial approval of the members present.

Messrs. David Fell, C.A.A., and Lawrence Hargrave were appointed Auditors for the current year.

Messrs. C. O. Burge and J. W. McCutcheon were appointed Scrutineers, and Mr. W. M. Hamlet deputed to preside at the Ballot Box.

The certificates of two candidates were read for the third time, of three for the second time, and of one for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

Lindeman, Charles F., Strathfield.
McMaster, Colin James, Longueville.

A letter was read from the Hon. Secretary of the Tate Memorial, Adelaide, calling attention to the Fund being raised to perpetuate the memory of the late Professor TATE, for twenty-six years Professor of Natural Science in the Adelaide University. It was proposed to erect a Memorial Tablet and to establish a Tate Medal for Geology.

Sixty-three Volumes, 158 Parts, 51 Reports, 5 Pamphlets, 3 Meteorological Charts, and 12 Geological and Topographical Maps, total 292, received as donations since the last meeting, were laid upon the table and acknowledged.

THE FOLLOWING PAPERS WERE READ:—

1. "The Gums, Resins, and other Vegetable Exudations of Australia," by J. H. MAIDEN, Government Botanist and Director of the Botanic Gardens, Sydney.

The introductory portion of the paper points out the difficulties in the collection of these substances in our sparsely populated territory, and that frequently those who have been supplied with material for commercial purposes or research have not been furnished with it in sufficient quantity or with proper data. The author gives a list of Natural Orders which in Australia yield both gums and resins, classifying them according as the gum or resin is the predominating substance. The paper contains a tentative list of those Orders which yield kinos, and a list is given of those exudations which specially merit the attention of the research chemist. Then follows the main portion of the paper, which contains notes on all the exudations known to the author, arranged in botanical sequence. References are given to papers by various workers, a number of exudations are now

referred to for the first time, and notes are given embodying the author's research and enquiry over a long series of years. The author hopes that his paper will be found useful to botanists, chemists, and those interested in the economic utilization of Australian vegetable exudations of our forests. The paper concludes with a bibliography of eighty-seven items.

2. "On the principle of continuity in the generation of geometrical figures in homaloidal space of n-dimensions," by G. H. KNIBBS, F.R.A.S.

The author discussed the philosophical basis of the idea of the continuous generation of geometrical figures, and shewed that we are compelled to admit the conceptional existence of a space of different orders, as well as dimensions, of infinity and zero; the interpretation of such being in all cases unambiguous. In interpreting algebraic equations, it was shown that in passing from the values -0 to $+0$ of the variable, where the branches of a curve exhibit infinite discontinuity, the result may depend upon the order of the zero. There may, for example, be no discontinuity for the first order of zero, unit discontinuity for the second order, and infinite discontinuity for the third. On a space homaloidal for finite figures of one order of infinity, but really of one dimension higher, it was possible to reduce the infinite discontinuity to continuity.

3. "Some theorems, concerning geometrical figures in space n dimensions, whose $(n-1)$ dimensional generatrices are n^{te} functions of their position on an axis, straight, curved, or tortuous," by G. H. KNIBBS, F.R.A.S.

In this paper the author shewed that certain theorems developed in two previous papers, might be extended greatly in generality, and were applicable to *quanta* determinations in n-dimensional space. The limitations as to the centre of gravity of the generatrix when the axis on which it generates was curved, or tortuous, were discussed, as also those applying to rotations about the axis. It was shewn that a theorem previously published in reference to

the application of the prismoidal formula to circularly ruled quadric surfaces, was an elementary case of a much more general theorem, and that a manifold infinity of analogous theorems can be developed for much more complex surfaces.

4. "Rock-holes used by the Aborigines for warming Water," by R. H. MATHEWS, L.S.

The author showed that the natives were in the habit of immersing heated stones in small quantities of water for the purpose of warming it for drinking, and in some cases to assist in cooking their food.

5. "Some Aboriginal Tribes of Western Australia," by R. H. MATHEWS, L.S.

Mr. Mathews also contributed an article on some aboriginal tribes of Western Australia, describing their divisions into intermarrying sections; lists of totems, comprising animals, plants, and other natural objects, attached to each of the sections, were also given. The laws regulating marriage and descent were explained, together with a brief outline of the structure of the language. Mention was made of their legends, knowledge of the cardinal points, and customs of genital mutilation, the whole concluding with a comprehensive vocabulary.

6. "Projects for Water Conservation, Irrigation, and Drainage in New South Wales, by H. G. McKINNEY, M. Inst. C.E.

The author of this paper described at the outset the conditions which are most favourable for extensive work for water conservation and irrigation. In this connection, Lombardy, Upper India, and Egypt were specially referred to, and the case of the latter country was described as being the best known combination of conditions favouring successful irrigation on an extensive scale. Applying to New South Wales the conditions referred to, the the author proceeded to point out that the Dividing Range is the only source to which we can look for sufficient water to supply any large scheme. In the coastal district the rainfall is fairly satisfactory; and as much of the alluvial land on the rivers is low-

lying, the question of drainage is a more important one than irrigation. It was pointed out, however, that irrigation has been tried successfully in a number of places in the coastal district, and it was explained that the fact of drainage being necessary did not by any means show that irrigation would not be successful in the same neighbourhood. The tableland and the valleys on the west side of the Dividing Range were next considered, and it was mentioned that some of these valleys are excellently suited for irrigation, so far as the soil and general conditions are concerned.

Coming to the great plains of the Central and Western Divisions of this State, the author called attention to the great magnitude and depth of the alluvial deposits as compared with the extent and height of the mountains from which they must have been derived. Consequent on these conditions there is a similar disproportion between the area which could be irrigated so far as levels of the country are concerned, and the quantity of water which can be made available for this purpose. The Murray and the Murrumbidgee are our only rivers from which supplies of water can be obtained for large irrigation projects, and even these rivers cannot be depended on for sufficient water in all seasons, unless storage reservoirs for augmenting the supplies of water in summer be constructed. In all the other western rivers the flow is liable to cease entirely, and sometimes this state of affairs continues for a considerable period. Storage reservoirs can remedy this when suitable sites are obtainable.

The large schemes for utilizing the waters of the Murray and the Murrumbidgee, were proposed by the author early in 1885, but the necessary surveys and levels were not authorised for several years afterwards. These surveys and levels showed that the scheme for a system of canals from the river Murray was practicable in almost every detail suggested. In the case of the Murrumbidgee, some changes proved necessary, and a modified scheme was accordingly prepared. Two projects were submitted in definite form to Colonel Home; the first for a system of canals in the district bounded on the south by the Murray and Edward

Rivers, and on the north by the Billabong Creek, and the second for the district between that creek and the Murrumbidgee. The first of these was adopted without modification, and the second with merely a change in the position of the headwork.

In addition to these two large projects, it was mentioned by the author that the facilities for constructing a canal on the north side of the Murrumbidgee, with its head a few miles below Narrandera, are little if anything inferior to the conditions on the south side of the river. The system of canals on the north side of the Murrumbidgee can be carried throughout the plains extending to Maude and Oxley. A subject which is generally overlooked, and about which little is known except locally, was referred to at some length. This is the great extent and value of the natural irrigation due to the overflow of the western rivers, especially in times of flood. This natural irrigation occurs on a large scale on the Murrumbidgee, the Lachlan, the Macquarie, and the Gwydir, and is of vital importance to the lower holders. It materially complicates the question of the construction of large works, as the rights of the lower holders must be taken into account. In his outline description of the Murray Canal Project the author mentioned that while the water can be delivered by gravitation for use on the land throughout a large district, a large amount of water power will be made available, particularly in the part of the canal above Berrigan, and also that Berrigan and Finley, as well as several other townships, can be granted abundant supplies.

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PROCEEDINGS OF SECTIONS.

PROCEEDINGS OF THE SECTIONS

(IN ABSTRACT.)

SECTION OF ECONOMIC SCIENCE.

This Section was constituted at a meeting of members of the Royal Society, held on 24th April, 1901, under the presidency of Professor Liversidge.

The inaugural meeting was held on 26th June, when an inaugural address was delivered by RICHARD TEECE, Esq., F.I.A., F.F.A., Chairman of the Section. A committee was appointed, consisting of Messrs. J. W. GRIMSHAW, JAMES HENDERSON, JOSEPH PALMER, and A. HALLORAN. A paper was read by Mr. JOHN PLUMMER on "Old Age Pensions *v.* Popular Thrift."

At the meeting held on 31st August, a paper was read by Mr. T. T. PETERSON on "A decimal monetary system."

At the meeting held on 19th September, a paper was read by Mr. JOSEPH PALMER on "A White Australia." A paper was also read by Mr. C. A. BENBOW on "The Pastoral Industry and our Western lands."

At the meeting held on 30th October, a paper was read by Mr. A. DUCKWORTH on "Commonwealth borrowings."

At the meeting held on 27th November, a paper was read by Mr. W. PEARSE, entitled "State *versus* National Banks."

The whole of the papers were printed by the authors for the use of members of the Section, and to facilitate the discussion of same at the meeting following that whereat the reading took place.

The session closed with the November meeting.

ENGINEERING SECTION.

During the session, six ordinary monthly meetings were held, while excursions were made by the members of the Section (by invitation) to the Sewage Farm at Botany, and the works of the Colonial Sugar Refining Co. at Pyrmont.

Monthly meeting held 19th June, 1901.

Mr. J. M. Smail in the Chair. Present twenty-five members and visitors. The Chairman delivered his annual address, the subject being "Municipal Engineering."

Monthly meeting held 17th July, 1901.

Mr. J. M. Smail in the Chair. Present sixteen members and visitors. In the unavoidable absence of the author, the Hon. Secretary read a paper by Mr. J. G. S. Purvis, entitled "Some notes on the purification of sewage." The discussion was adjourned till a later meeting.

The discussion on Mr. C. W. Darley's paper on "Curved dams," read at the previous December meeting, was then proceeded with, Professor Warren, and Messrs. Cardew, Deane, Barraclough, Cook, and Wilmott taking part. In the absence of the author, Mr. L. A. B. Wade replied to the discussion.

Monthly meeting held 21st August, 1901.

Mr. J. M. Smail in the Chair. Present eleven members and visitors.

The discussion on the paper by Professor Warren and Mr. S. H. Barraclough, entitled "Experiments on the strength of brick-work, when subjected to compressive and transverse stresses," read at the previous December meeting, was proceeded with, Messrs. Cardew, Nangle, Houghton, Kidd, and Haycroft taking part. Professor Warren replied.

The discussion on the paper by Mr. J. G. S. Purvis, read at the previous meeting, followed, Messrs. Houghton, Kidd, and Cardew, taking part. Mr. Purvis replied.

Monthly meeting held 18th September, 1901.

Mr. G. H. KNIBBS in the Chair. Present sixteen members and visitors.

Professor WARREN read a paper on "The strength of concrete," and Mr. J. H. CARDEW read a paper entitled "Notes on the underground workings of a colliery in the Western Coalfields of New South Wales." The discussion on these papers was adjourned until a later meeting.

The Chairman then gave a demonstration of the construction and working of a large geodetic level, exhibited by him.

Monthly meeting held 19th October, 1901.

Mr. J. M. SMAIL in the Chair. Present fifteen members and visitors.

Professor WARREN's paper on "The strength of concrete," read at the previous meeting, was discussed by Messrs. CARDEW, DAVIS, WILMOTT, KNIBBS, WADE, ROSS, KIDD, COWDERY, and the Chairman. Professor WARREN replied.

Monthly meeting held 18th December, 1901.

Mr. J. M. SMAIL in the Chair. Present thirteen members and visitors.

The Committee for the ensuing year was elected as follows:— Chairman: Mr. H. G. McKINNEY, M. Inst. C.E. Hon. Secretaries: Mr. S. H. BARRACLOUGH, M.M.E., Assoc. M. Inst. C.E., and Mr. H. H. DARE, M.E., Assoc. M. Inst. C.E. Committee: Messrs. PERCY ALLAN, M. Inst. C.E., G. R. COWDERY, Assoc. M. Inst. C.E., J. DAVIS, M. Inst. C.E., H. DEANE, M. Inst. C.E., J. I. HAYCROFT, M.E., M. Inst. C.E.I., H. E. ROSS, W. H. WARREN, M. Inst. C.E., M. Am. Soc. C.E., J. H. CARDEW, Assoc. M. Inst. C.E. Past Chairmen: T. H. HOUGHTON, M. Inst. C.E., M. Inst. M.E., NORMAN SELFE, M. Inst. C.E., J. M. SMAIL, M. Inst. C.E.

A paper by Mr. W. E. COOK, M.C.E., M. Inst. C.E., on "Testing of stoneware pipes used in reticulation sewers," having been printed and circulated before the meeting, was taken as read.

In the discussion on this paper, Messrs. Houghton, Birks, Kidd, Cowdery, Peake, and the Chairman took part. Mr. Cook replied.

The discussion on Mr. Cardew's paper, entitled "Notes on the underground workings of a colliery in the Western Coalfields of New South Wales," read at the September meeting, was proceeded with, some notes communicated by Mr. R. Thomas being read by the Hon. Secretary.

After a vote of thanks had been passed by the meeting to the retiring Chairman and Hon. Secretaries, the formal business was concluded, and the rest of the proceedings took the form of a "smoke" and social evening.

ANNUAL ADDRESS.

By J. M. Smail, M. Inst. C.E.

[*Delivered to the Engineering Section of the Royal Society of N. S. Wales, June 19th, 1901.*]

In opening the Session for 1901 I wish in the first place to tender my thanks to the members of the Section for the honour they have conferred upon me in electing me as Chairman for the session. The nation has lately had to deplore the loss of our beloved Queen, and this must directly appeal to the feelings of the Engineers inasmuch as the Victorian era has been conspicuous in the development of engineering science in all its branches. No Sovereign has taken a deeper personal interest in the development of science than Queen Victoria, and to this interest we may in a great measure attribute the successful issue of the various departments of science.

Like my predecessors I have had some difficulty in selecting a subject upon which I could address you, and in looking round for one which has not been previously dealt with, I found the difficulty increasing, and like the man, who when in doubt, came back to the first principles, I decided to take as my subject one in which I might claim to have had some experience, and that is Municipal Engineering. In dealing with the subject I propose to give a short review of the development of Municipal Engineering in connection with this City and with other matters connected therewith; secondly Municipal engineering in its general bearing in the interests of the ratepayer; and finally, an attempt to outline an ideal Municipal Government in its relation to engineering.

Prior to the incorporation of the City of Sydney in 1848 all works of improvement in connection with supply of water and formation of streets, etc., were carried out under officers of the Imperial Government and by convict labour to a large extent.

The newly formed City Council entered upon its duties in the same year, but after a troubled existence and dissatisfaction on the part of the citizens, the Council was abolished and a new regime under three (3) Commissioners was inaugurated. The Commissioners came into power in 1854 and had an existence for three years, viz., to the end of 1857, when in turn they were displaced by a second Municipal Council who assumed control of the city affairs in the beginning of 1858, and at present controls the civic affairs in a modified form.

It was during the Commissioners' term of office that Municipal Engineering in its true sense may be said to have assumed concrete form. At the time they assumed control the water supply was limited to the old "Busby Bore," which was constructed in 1824 by convict labour under the direction of Mr. John Busby, Mineral Surveyor for the Imperial Government. During time of drought the supply from the "Bore" was so precarious that the citizens had to fall back on the supply from private wells, or obtain their daily wants from the nearest pump, or await the arrival of the water cart from which they could obtain a supply at 3d. per bucket. The Commissioners initiated investigations for obtaining a more abundant supply of water in the locality of Botany, which included a series of earthen dams with timber cores and erection of pumping machinery near the shores of Botany Bay. This work was not, however, carried out beyond the initial stage by the Commissioners. The most important municipal engineering work the Commissioners commenced was a system of sewerage, on what was then termed modern lines. Prior to this work being commenced a trigonometrical survey was made of the city, as well as a detail survey shewing every house, watercourse and other feature of importance.

The institution of select committees had at that early period of municipal government to be reckoned with before the authority could get to work, and a perusal of the evidence given at the committee, both in connection with the necessity for a trigonometrical survey, and mode of constructing the sewers as to form

and material, affords some amusing reading when viewed after a lapse of nearly half a century. An eminent authority of the day occupying the position of Surveyor-General was very wrath at the temerity of the municipal authority in commencing a trigonometrical survey of the city for the purpose of water and sewerage works. In reply to a question of the chairman as to whether the survey made by the Government included the whole of the city, he replied "Yes, this is the trigonometrical survey itself," (producing the original triangulation in pencil on a sheet 5 ft. 6 in. × 6 ft. 6 in.). "This was completed upon the smallest sized table in my London lodgings, and I cannot but envy those people who can obtain acres of table and paper for the survey of a piece of ground that a man might leap his horse across." In fixing the size of the sewer the same authority was a little more liberal in his ideas, viz., in his opinion the sewer should be of very great dimensions, and on being asked as to the limit of the dimensions, he stated that it should be "large enough for a horse and cart to go in and out." One of the committee improved upon this by stating that in the old Roman sewers a cart with a load of hay could go in and out, this appeared to settle the question as to the dimensions of the main city sewer as the two were of the same opiniun. From a perusal of the final report of the committee it is manifest that at that period, 1854, the legislators of the day were alive to the interests of the citizens in the preservation of health. It is interesting to read the names of the committee, all of whom have passed away, but the memory of their public services remain. The committee consisted of Mr. (the late Sir Henry) Parkes, the Chief Commissioner of Crown Lands Mr. (late Sir Charles) Cowper, Mr. Flood, Captain King, the Colonial Treasurer, Mr. Holden, Mr. Nichols, and Mr. Allan, the late Chief Justice, Sir James Martin, being chairman. The City Engineer who initiated the work was the late Mr. B. Rider, and the officer in charge of the trigonometrical survey was the late Mr. W. H. Barron.

The examination of the latter gentleman by the committee also affords amusing if not instructive reading. A number of the

committee who did not appear to attach much importance to the preliminary survey work which was being carried out, but were more concerned in getting the work of construction started, wanted to know if the main sewer could not be carried out without waiting for the survey. Needless to say that the witness was of opinion that some persons might venture to do so, but no engineer would attempt it. The Commissioners eventually obtained the necessary legislative authority for expenditure, and proceeded to carry the scheme into execution. During their tenure of office several engineering works of a municipal character were proposed, such as public baths, and an improved system of removal of house refuse, but, whether the commissioners lacked the ability to meet the public demands or the necessary funds, it was quite evident that the ratepayers knew what they wanted, for after a fitful existence, the Commissioners had to make way for a new City Council which assumed control in 1858.

From this year onward it might be said the municipal engineering in its true sense was carried on with vigour. An improved water supply with an efficient pumping plant at this time was installed at Botany. Reservoirs were constructed at Crown Street and Paddington, and the old Busby Bore gradually became a thing of the past, and the perambulatory water cart became extinct. Reticulation mains were laid all over the city and a constant service became ensured. Main sewers with numerous branches were constructed so that within twenty years of the inception of the new Council, the cesspit with its attendant abominations almost became a thing of the past. The proper formation and macadamizing of streets and roads became an important part of municipal work, as well as street scavenging. The construction of wharves and buildings was also entered upon as well as improved street lighting. The abattoirs were removed from the City, and more attention was paid to the slaughtering of stock for the wants of the community, and also regulation of street traffic. The City was not only able to supply water for the ratepayers but also to the immediate suburbs, until the requirements

increased to an extent which taxed to the utmost the capacity of the Botany supply, and at the same time the pouring of the sewage of the city for nearly a quarter of a century into the harbour caused alarm to the citizens. This led to the appointment of Commissioners whose labours culminated in recommending a more extensive source of supply, and a new system of sewerage which would divert the sewage from the waters of the harbour. When the schemes were brought into operation, the control of same was transferred from the City Council to a Board, which is municipal in character and government, inasmuch as the majority of the members are indirectly elected by the ratepayers, who have to pay for the benefits derived from their services.

As the City increased so did the suburban areas in a greater degree, necessitating carrying out works of street forming, stormwater channels, kerbing, etc., and in many cases the construction of roads reflected considerable credit on the responsible officers, notwithstanding the chronic state of scarcity of funds. Having sketched somewhat imperfectly, I am afraid, the development of municipal engineering in connection with the metropolis, and before leaving this portion of the subject I would like to draw your attention to some photographs and sketches in connection with the early system of water supply to the city. I might state that two of the sketches are from the pencil of Mr. C. H. Woolcott, for many years Town Clerk of the city and connected with the City Commissioners who preceded the Council, and to whom as a young aspirant for honours in the field of engineering I am indebted for much sound advice and assistance.

In considering the second point, viz.:—Municipal Engineering in its relation with the ratepayer, I think it is obvious that whatever may be dispensed with, there is one consideration which is paramount and that is, funds. It is at this point that the ratepayer is indispensable, for without him, "funds" would be a minus quantity. When we compare the municipal government of the city and suburbs, with say, provincial towns in Great Britain and America, we cannot but be forced to the conclusion that, notwith-

standing a century of experience, there is an inordinate amount of grand-motherly interest taken by the State in matters of pure Local Government. In using the term "ratepayer" it is intended to be distinct from that of "taxpayer," the former implies a direct service, and the latter an individual who may have very decided opinions as to the value he should receive in return, whereas with the other his opinions may be very hazy. Owing to the grand-motherly interest before mentioned, the local bodies not only in the metropolitan area but in the country districts are relieved of all anxiety in carrying out works connected with water supply and sewerage, fire service, tramways, etc., and have only to control such works as street formation, pavements, minor bridges and drainage, but have to pay in the long run for the whole of these services.

Even with the modified system of local administration it is possible that the best return is not obtained for the expenditure, inasmuch as it is not always the best qualified man who is chosen to carry out local works, and the result is that the local bodies are often plunged into difficulties and law suits. It is not long ago, that two local bodies had to meet very heavy liabilities in connection with defective local works of drainage which, if designed by a competent man, would have fulfilled the purpose for which they were intended and saved the funds expended in law. I think it will be generally conceded that, when a man is sick he naturally would consult a qualified medical man, or if he wishes to go to law to defend his rights he would consult a qualified lawyer, but in a matter pertaining to engineering, and more especially municipal engineering, a large number of aldermen, directly they take their seats, seem to be inspired with the opinion that they are engineers by some heaven born process. Holding such opinions it is obvious that amateur engineering would have full play, and the qualified man would under the circumstances have a most invidious task to perform. Under such circumstances Municipal Engineering would not benefit the ratepayer.

Turning from this side of the question to the other, viz., by the employment of a properly qualified man who, having a reputation to lose, is not likely to place his Council or himself in an invidious position with the general ratepayer, there is an old saying that the cheapest things are not always the best, and this holds good in municipal engineering as in domestic or commercial life. It might be said that a local body could not afford to pay a professional man for his continual services; this may be the case with many bodies, but does not prevent retaining the services of a qualified man to advise the local body in matters of import. It is not rarely the case that most important matters are left to the judgment of men, who may be thorough tradesmen in their particular lines, but have not been trained in the fundamental principles which govern the very case upon which they are advising one, and owing to the ignorance of these principles work has been carried out which could only be characterised as absolute waste. Had an experienced and qualified man been employed the dangers would have been anticipated and provided for. In such cases efficiency and economy would have been secured, and this is an instance where municipal engineering interests the ratepayer.

In sketching an ideal municipal government in its relation to engineering we must seek for models in Great Britain, which is beyond all doubt the home of municipal government in its highest sense. In Great Britain the municipal engineer and surveyor holds a high position, and the duties are so varied and embrace so many items of administrative and constructive work, that a large amount of time would be required to deal with them in their entirety.

The last annual report of the Local Government Board shews that since 1871 the local authorities have incurred upon the strength of their borrowing powers an indebtedness of £150,000,000 for sanitary works and other improvements. This vast sum is in addition to and quite independent of, the annual cost of works defrayed from current expenditure. The amount of loans sanc-

tioned by the Local Government to local bodies in 1871 was £267,000 whilst in 1896 the amount totalled 5½ millions of pounds. The nature of these works comprised road making and maintenance, with bridge and viaduct work, tramways, sea and river walls, water and sewerage systems, public lighting, isolation hospitals, public offices, free libraries, mortuaries and other buildings incidental to municipal administration, public parks and pleasure grounds, fire brigade control, and supervision of new buildings. The foregoing may be taken as an example of municipal government as it is understood in Great Britain and also as in America, and there are many points which may be copied in connection with the former, and many which can well be avoided as far as the latter is concerned.

It may be of interest to review the extent of control exercised by the municipal government in some of the leading cities of Great Britain, and a few have been selected from the Municipal Year-book. Birmingham with a population of 301,241 and rateable value of £2,254,666 and area of 12,705 acres. The advance in municipal government in this city dates from the time of Mr. Joseph Chamberlain's mayoralty, during which two important services were municipalised. In addition to these services the control extends over markets and slaughter houses, tramways, baths and wash houses, cemeteries, libraries, museum and art gallery, technical schools and school of arts, artisans' dwellings, sewage farms, hospitals, industrial school and asylums. The greatest enterprise undertaken by this corporation was the acquisition in 1876 of an overcrowded and unhealthy area in the centre of the town, of 90 acres with 3,744 houses and 16,596 inhabitants. The gross cost was £1,308,221, under this scheme the centre of the city has been completely transformed, where slums were, the best business streets of the city now stand. To carry out the work a special rate was necessary, but a valuable asset has been obtained. The sites are let on leases of 75 years and contain the best buildings of the city. In the meantime the Corporation receives a ground rent, and on the expiration of the

leases the Corporation becomes the owner. The value of the municipal estate three years ago was two and a quarter millions.

Another important municipal centre is Manchester, with a population of 534,299, with a rateable value of £2,955,775 and an area of 12,911 acres. This city possesses the most profitable markets in the country, yielding in 1896-7 a surplus of £12,000. The gas undertaking paid over in 1897 the sum of £40,000 in aid of rates, and the competing electric lighting service, although a new enterprise, handed over £10,000 as surplus profits. Tramways and artisans' dwellings are also under municipal control, and other services as in Birmingham are controlled.

Glasgow is an instance of municipal development and to what perfection civic administration can attain. The citizens of Glasgow are subject to the influence of good government at every turn. The Corporation has perhaps carried out bolder schemes and undertaken greater and newer enterprises than any other public city. The civic control embraces every service which contributes to the health and comfort of the citizens, and is largely represented on the Clyde Navigation Trust. Under the Glasgow Corporation Loans Act the borrowing powers amount to £11,511,330. Sums set apart as a sinking fund amounted to £2,473,712 in 1897, having a net borrowing power of £9,037,618. Items of expenditure are interesting in showing the wide range of civic control, viz.:—Police establishment £123,662, Cleansing Department £112,586, Lighting £61,318, Fire Brigades £15,380, Sewers, Bridges, Repairs £61,194, Hospitals £38,660, Sewage Purification £10,313, General Sanitary Expenses £22,923. The sewage purification scheme cost over £600,000. The population is 715,579 and the rateable value four and a half millions.

Edinburgh is another example of complete municipal government. The population is 292,364, and the rateable value is £2,241,730. In additing to controlling all services enumerated in connection with towns mentioned, the civic body takes a hand in the control of the University and Carlton Hill Observatory, shares in maintaining a veterinary college, and is the governing

body of Trinity College Hospital. The items of annual expenditure under the extent of control, viz., Watching £52,513, Lighting £30,063, Cleansing £48,775, Fire Brigade £7,575, Parks £7,825, Sewers and Drains £23,063, Public Health £19,502.

If we turn to Ireland and take one of the largest cities, Belfast, we still find the same extensive system of civic government existing. Belfast has a population of 313,400, and a rateable value of £931,420. The Corporation has the gas and electric lighting as well as markets, baths, parks, technical schools, sewerage, fire brigades, and libraries under its control.

If we cross the Atlantic we find the same progression in municipal engineering with regard to water and sewerage, transportation, lighting, scavenging and other works connected therewith, but the principles of civic control are not models upon which we would like to build up an ideal civic government.

Coming nearer home we find that municipal government as it has been carried out in older countries does not exist, the controlling powers being from time to time taken away and invested in other bodies, Movements have been made in the direction of amalgamating several boroughs with the City, on the lines of the London County Council, while on the other hand another modified scheme has been advanced, neither of which appears to have advanced beyond the initial stage. Several reasons might be advanced to account for the movement not making any advance. It might be attributed to the apathy of the people concerned, or to the fact that the legislators were more concerned with State politics than domestic legislation. Whatever the cause may have been in the past, there is a hope, now that all questions of national import are relegated to the Federal Parliament, the State Legislature will have time and inclination to deal with matters pertaining to domestic legislation.

The existing City Council was inaugurated a few years ago after the proclamation conferring responsible government on the State of New South Wales, and history may repeat itself after a lapse of nearly half a century by Local Government becoming a

living factor in the welfare of the State shortly after the inauguration of the Commonwealth, a consummation devoutly to be wished for.

All the examples of civic government quoted are the results of development, and the general trend of such development has been in the direction of unification of the principal services which contribute to the health and comfort of the ratepayers under one controlling body. The original scheme of the London County Council might be cited as an example of attempting too much in the direction of consolidating civic government. This scheme included the whole of the vestries or local councils outside the City of London, and the administration of all internal affairs of such bodies was found to be unworkable, and it is believed that the object now is to administer the larger services, leaving the minor interests to be administered by the local bodies as heretofore. It would appear therefore that as a preliminary measure to any future scheme of Local Government, that a measure dealing with the amalgamation of the different services which partake of a civic character, under one controlling body, would commend itself for consideration.

The ideal form of municipal government would include the control of services connected with sewerage and drainage, water supply, lighting (gas or electric), tramways, markets, abattoirs, artisans' buildings, baths, roads and streets with bridges etc., street cleaniug, refuse destruction, parks, wharves for civic purposes, fire brigades, lodging houses. With such works the municipal engineer and surveyor of the future will have ample scope to display his ability, and considering the advantages which have been provided by the State in connection with the Technical College and Engineering School of the University, there is every hope that qualified men will be available to take up the duties.

The consideration of the site for the Federal City may be productive of good in the direction of inaugurating a system of Local Government on a broad and firm basis. It is to be hoped

that in laying out the city the mistakes of the past may be avoided. One of the most serious troubles in connection with carrying out a sewerage scheme is the absence of lanes or drainage reserves. The lines of subdivision appear to be laid out with total disregard to requirements of a sewerage system. Also that the anomaly of a building act being in force in the city, and the total absence of one in the suburbs, may not be repeated. The control of civic affairs could be consolidated under one body without interference with efficiency of administration. The future Federal City concerns every person in the Commonwealth both as to position and internal administration, and it is to be hoped that with its advent the ideal civic government may be attained.

SOME NOTES ON THE PURIFICATION OF SEWAGE.

By J. G. S. Purvis.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, July 17, 1901.*]

In reviewing the progress that has been made in the purification of sewage I purpose confining myself to the treatment that has been meted out to the sewage arriving on the Sewage Farm at Botany and Arncliffe from the Southern and Western Systems.

The sewage of Sydney has four principal outfalls—The Northern System discharging at Ben Buckler, Bondi; the Southern discharging on to the Sewage Farm at Botany; the Western discharging on to the western end of practically the same farm at Rockdale, while the sewage of North Sydney is discharged at Willoughby Bay, Middle Harbour.

The sewage falling into the Northern System is discharged into the Pacific Ocean at Ben Buckler, without any previous treatment. The sewage falling into the Southern System, in addition to the

ordinary domestic sewage, consists of a considerable proportion of trade refuse from breweries, boiling down establishments, etc. After arriving on the northern bank of Cook's River, where all the heavier solids are screened out, it passes under the river by means of an inverted syphon, and is then delivered on to the farm by means of an open carrier. This carrier has various outlets along the route by means of which it is distributed on to irrigation beds and filtration tanks.

The heavier solids screened out of the sewage at the screening house have up to the present been grabbed out of the wells and conveyed over a temporary bridge spanning the river on to the farm, and there ploughed into the land, the ultimate result being eminently satisfactory as far as the disposal of sludge is concerned, but the cost of handling to say nothing of the objectionable nature of the work leaves ample room for improvement. As a step in that direction, it is intended to tap the sludge wells and force it across the river by means of a line of cast iron ball and socket submarine pipes, using compressed air for that purpose. This pipe will deliver into a reservoir tank from which it will be taken by carts and distributed on to the beds where required.

The total area of land over which the sewage from the Southern outfall is distributed amounts to 71 acres, of which 13½ acres are under cultivation, and 57½ acres are used as filter tanks. The whole area is underdrained with the exception of three tanks comprising 25 acres, which are at present being dealt with. Some of these drains are constructed of 6 inch diameter glazed stoneware pipes, jointed with mortar, consisting of one of cement to five of sand thus rendering it quite porous. Others are constructed of unglazed earthenware pipes well scored on the outer skin with the idea of rendering them more porous, and jointed with cement in a similar manner to the above. The drains are laid at an average depth of about 4 feet, and discharge into Cook's River and Botany Bay.

As time went on the natural increase of flow proved itself too much for this area to deal with, the rate of filtration being too

tardy, and various methods were tried with a view to facilitate the entry of the filtrate into the drains. With this object in view pipes were inserted in the line of drains having side inlets, these inlets being closed with wove wire gauze discs having 3,600 meshes to the square inch. These discs acted very well for the time, the rate of discharge being very much increased, but after about twelve or eighteen months they perished and required renewing. The price of a new disc together with the cost of inserting it was found to be too expensive, so another system was tried, and after about three years' experience, has been found to work admirably so far as rapidity of disposal is concerned.

The sewage falling into the Western System is purely domestic sewage, derived from the whole of the Western Suburbs as far as Strathfield, which on its arrival on the farm at Arncliffe passes through screens, thus ridding it of all rags and other coarse solids which would otherwise only choke the distributing valves and pipes. The total area of land over which this sewage is distributed amounts to 118 acres, the whole of which is used as filter tanks. Seventy-three acres have been provided with underdrains consisting of unglazed porous pipes of the agricultural pattern, having coir fibre mat joints, and as this system of jointing is the only one now adopted, I will describe it in detail.

Plain unglazed pipes 6 inches diameter, of the agricultural type are laid with their ends 2 inches apart, and around the open joint a coir fibre mat 9 inches wide is wrapped and tightly sewn on, and on the joint thus made a pad of loose fibre is laid, the whole joint then being surrounded with about one cubic foot of coarse sand. The sewage, after percolating through about four feet of sand, passes through the mats and enters the pipes. Each pipe is two feet long, and altogether about twelve miles of drains have been laid, which means that nearly 32,000 mats have up to the present been utilized.

The system of under drainage at this end of the Sewage Farm consists of large central mains 18 inches diameter glazed stoneware pipes, having cast iron pipe outlets discharging into Muddy

Creek and Cook's River. Into these mains the porous lines deliver the filtered sewage, the whole being controlled by valves on the main outlets.

Results of Treatment.—Western and Southern Systems—There is no doubt that without this, or an equally rapid system of filtration, the whole of the raw sewage arriving on the farm could not be disposed of on the area mentioned, and it is this rapidity of disposal which is the controlling factor in the whole scheme at present in vogue; but when the final state of the effluent comes to be considered it is a question whether a higher degree of purification could not be obtained at a much less cost and on a smaller area. The whole of this filtration area is divided up into different beds with distributing pipes running down the dividing banks having oflet pipes, by means of which the beds are flooded. The sewage then percolates down through the fine sand and finds its way into sub-drains, and thence to the outlets discharging into the river. Its condition is then neither more nor less than finely screened sewage, having a low degree of purification due to anærobic agencies, but is then no worse than the river into which it discharges, hence no harm is done.

The very essence of sewage purification is the ultimate destruction of undesirable matter, and as no matter what you do with sewage, it is eventually rendered innocuous by nature, instead of retarding it the object should rather be to make the conditions so favourable that the decomposition is conducted on lines resembling those of nature as much as possible. The lime process is the very reverse of this, as by the use of large quantities of lime the living organised bodies such as bacteria are destroyed, and seeing that such bacteria give rise to that phenomena known as putrefaction, it simply means that until the effect of the lime has worn off the oxidising organisms cannot get to their work and decomposition which must come, is thereby retarded. Even if the lime process as generally carried out were a success, as far as the final state of the effluent is concerned, the question of cost

renders it prohibitive, and the disposal of the sludge is an intolerable nuisance.

This then appears to have been the position of the sewage question in Sydney and suburbs within very recent years, although prior to this the subject of bacterial purification or disposal of sewage had arrested the attention of the Engineer to the Metropolitan Board. Certain well defined principles are already recognised and generally accepted, nevertheless the following processes and operations are quite old in application in the field of sewage disposal. (1) Sedimentation. (2) Reduction or liquefaction of the solids by anærobic bacteria. (3) Submerged inlets and outlets to cultivation tanks. (4) Exclusion of light and air. (5) Artificial ventilation. (6) Discharge over weirs or cascades for the purpose of aeration. (7) Periods of contact with filtering material, rest and recuperation—which is simply the old system of intermittent downward filtration adopted on most sewage farms. This being so, there is nothing novel in the action which is produced in the modern filter or septic tank, but there certainly is in some of the gears or devices which have been designed for the purpose of controlling the distribution of the sewage.

In 1898 the Metropolitan Board decided to carry out a series of experiments on a small scale, in order to ascertain whether the sewage delivered on the farm by the Southern System would be amenable to treatment by the septic process. The tanks were simply wrought iron tanks of four hundred gallons capacity, and two different processes were adopted, viz.:—the septic tank and the Scott-Moncrieff systems. After a very carefully conducted series of analyses by Mr. Doherty of the Board of Health, the following average results were obtained :—

Raw Sewage—

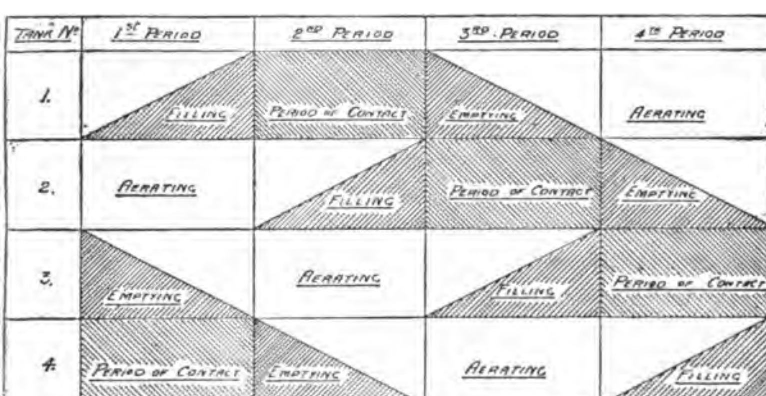
Total solids	657	parts per million
Chlorine	120	„
Free ammonia	43	„
Albuminoid ammonia	25	„
Oxygen absorbed in four hours...	64	„

After being in contact with the filters for varying periods the following percentages of purification were obtained :—

Percentage of improvement based on diminished quantity of albuminoid ammonia.		Percentage of improvement based on diminished amount of oxygen consumed.	
Coal Filters.	Coke Filters.	Coal Filters.	Coke Filters.
82%	82%	63%	65·5%

After obtaining such satisfactory results from the sewage of the Southern System, the Metropolitan Board decided to subject the sewage of the Western System to a similar course of experiments with the exception that in place of the septic tank, an installation on the Scott-Moncrieff principle should be adopted, of sufficient capacity to deal with sewage derived from 160 persons, allowing them forty-two gallons per head per day.

The tanks which were built in brickwork set in cement mortar consist of one large cultivation tank and four contact filters, the rate of flow being regulated so as to admit of eight hour cycles— two hours filling, two hours standing full, two hours emptying, and two hours aerating. The upward or cultivation tank was provided with a false bottom, 12 inches from the floor, and consisting of old railway iron built into the walls and bricks resting on the flanges having two inch intervals.



The filtering material in this tank consists of Nepean gravel graded upwards every foot from about 4 inch gauge to that of the size of a pea. The filtering material in the contact beds consists of coal in two cases, and coke in the others, graded from 3 inches to 1 inch. It was found impossible to adhere absolutely to the eight hour cycles with an uniform rate of flow, on account of the interstitial spaces in the coke beds exceeding those of the coal, the excess amounting to as much as 30%.

The main carrier was tapped by a 4 inch cast iron pipe provided with a screw-down stop valve. This entered the bottom of the cultivation tank just underneath the false bottom, thus causing the sewage to pass upwards through the filtering material. The main cultivation tank is 25 feet 3 inches long by 9 feet by 5 feet 1½ inch deep, and has an estimated net capacity of 3,636 gallons.

On the 24th January of this year the rate of flow was carefully measured, so as to give as near as possible the eight hour cycles. The contact beds are each 10 feet by 6 feet by 4 feet deep. The holding capacity of the beds filled with coal was found to be 475·6 gallons, and each of them took 1 hour 42¾ minutes to fill. The holding capacity of the tanks filled with coke was found to be 622½ gallons, and each of them took 2 hours 13½ minutes to fill. From these figures it will be seen that the voids in the coal filling is 33%, and in the coke filling 43·5%, and that the rate of flow is 4·66 gallons per minute or 626,300 gallons per acre per diem.

This is hardly a fair way of making a comparison as the depth of the tanks is not admitted as a function, but when such is admitted it will be found that 3·16 gallons of sewage are purified (to a degree to be afterwards stated) per cubic foot of gross tank capacity per twenty-four hours, and that ·316 cubic feet of gross tank capacity is required per gallon per capita for this particular degree of purification. The flow of sewage through this installation was started in November 1st, 1900. On December 3rd of the same year, Mr. Doherty of the Health Board under directions of Mr. Hamlet, Government Analyst, commenced his analyses, and on March 26th 1901, reported as follows:—

IN PARTS PER MILLION.

Average composition—Raw Sewage.		Effluent from Cultivation Chamber.	Effluent from Coke Filter.	Effluent from Coal Filter.
Total solids ...	... 1088·33	715	728·75	776·6
Chlorine ...	... 375·	296·66	296·	293·3
Free ammonia ...	20·75	40·	26·	29·3
Albuminoid ammonia	8·775	2·8	2·12	1·9
Oxygen absorbed ...	16·1	11·716	10·82	10·35
Nitrous nitrogen ...	0 to ·2	trace	·4	·45 to 0
Nitric nitrogen ...	0	trace	2·5	4·5 to 0

PERCENTAGE OF IMPROVEMENT.

Based on diminished quantity of albuminoid ammonia.		Based on diminished amount of oxygen consumed.	
Coal Filters.	Coke Filters.	Coal Filters.	Coke Filters.
76%	71%	72·5%	78·5%

An effluent taken from one of the coke filters on the 18th April was examined on the 8th of May and found to be free from any unpleasantness whatever.

As stated previously, the coal filter took 1 hour 42¾ minutes, and the coke filter 2 hours 13¼ minutes to fill, or a mean of 1 hour 58 minutes. Had all the filters been of coke, the rate of flow necessary to fill the filter in two hours would be 7,470 gallons per twenty-four hours, which means that the tanks would deal with the sewage from 178 persons instead of 160 for which they were designed.

The tanks had not been long in operation before it was found that with a 4 inch diameter valve, the opening required for the necessary rate of flow was too restricted and chokages were of frequent occurrence. Then again the rate of flow varied according to the rise or fall of the sewage in the carrier. It was therefore decided, in order to bring the installation into line with ordinary working conditions, to introduce a flow regulator. This regulator was inserted in a brick pit between the main carrier and the tanks, and consisted of a conical valve actuated by a float, which, as soon as the sewage attempted to rise in the pit, raised

the float and closed the valve. This has been found to work admirably, and the rate of flow is now practically constant.

With regard to the controlling gear for regulating the distribution of the effluent from the cultivation tank into the coal and coke filters, the whole thing depends on the filling of each tank in succession. When one tank fills it shuts off the supply to itself, starts the next one in sequence to fill, and starts the next one behind it to empty. This is brought about in the following manner:—The sewage after rising up through the cultivation tank passes over a weir and is collected in a distributing channel. The external wall of this channel is provided with four cast iron traps, one to each tank. Each contact tank is provided with an air bell placed at such a level that just at that moment when the tank is full, air is forced out of the bell, locks the trap and shuts off the supply. Each contact tank is also provided with a trapped syphon standing on the floor and discharging through the wall into a channel common to all.

A cistern built into the external wall of each tank, contains a float arm actuating two valves—one connected to the bell of that particular outgoing syphon to which the cistern belongs, and the other connected to the trapped inlet of the next tank in sequence. Each cistern is connected to the next tank in sequence by a pipe which conveys the overflow when the said tank is full. When a tank is filling, the one behind it is standing full and the one in front of it is standing empty. When full, air is forced out of the air bell, locks the trapped inlet and stops any further supply as has already been stated. At the same time sewage overflows into the cistern of the tank behind it, raises the float arms, releases the air from the trapped outgoing syphon, causing its discharge, and also releases the trapped inlet to the next tank in sequence causing it to start filling, and so on without ceasing. The outgoing syphons are regulated so that the rate of discharge can be controlled to anything predetermined.

In concluding this short review, seeing that the results from the septic tank and the Scott-Moncrieff systems as laid down here

are practically the same, the question naturally arrises. Is this the best we can do? or are any of the other too numerous to mention processes in vogue likely to give a better result?

To answer such a question it must be borne in mind that both of these systems are primarily anaerobic, and the much argued question as to whether the preliminary breaking up of the solids and preparation for the final oxidation is necessarily anaerobic has not yet been settled.

From the investigations of Dr. Clowes at Crossness, on a 13 feet deep coke bed and on the coarse grain bed at Sutton—both of which receive the sewage intermittently, the action upon the organic matter retained in it, was found to be purely aerobic, and the effluents have frequently reached the nitrifying stage. It therefore appears to the writer that apart from any question of expediency, equal results can be attained by either. In practice, however, the use of a tank, be it septic tank or a Scott-Moncrieff; has much to recommend it.

In the first place such a tank as either of the foregoing is able to contend with any rush of sewage and the nature of such incoming sewage can be to a certain extent somewhat equalised, and a smoothing influence exerted on the sewage leaving the tank, which of itself is most important. Then again no screening is necessary as in the case of the coarse grain filter, where if not screened most of the solids remain on the surface. For these reasons a preliminary tank seems to be desirable, nor is it essential that such tank should be covered in, since air and light are sufficiently excluded naturally, to enable the anaerobic organisms to perform their functions; but the possibility of nuisance arising from an open tank is another question which can only be settled by time and experience. From the writer's acquaintance with open tanks or carriers containing sewage the conviction is forced upon him that they are not above suspicion.

Through the courtesy of Mr. W. M. Hamlet, Government Analyst, I am able to give you the percentage of purification

effected by the septic tank installation at Rookwood Asylum. The results are based upon the chemical analyses of average samples of crude sewage, and of average samples of effluents, each taken at the same hour on the same day.

Dates.	By the amount of oxygen consumed in four hours.	By the difference in the albuminoid ammonias in both effluent and crude.
24th February, 1900	80	83
16th March, 1900 ...	85	83
25th April, 1900 ..	75	89
	Mean 82	

Finally, the writer's object in placing this short paper before this Society is rather to promote discussion than to impart knowledge; also in the hope that the lay mind will be solaced by the fact that the Metropolitan Board are fully alive to the importance of this matter, and that a proper solution of the sewage problem, such as they are endeavouring to obtain is the best means of conserving the public health.

THE STRENGTH OF CONCRETE.

By W. H. Warren, M. Inst. C.E., M. Am. Soc. C.E., Challis Professor of Engineering, University of Sydney.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, September 18, 1901.*]

The tests described in this paper, on concrete subjected to compression, transverse, and tensile stresses have extended over several years, and it was thought desirable to publish them for the benefit of those who are engaged in the construction of works in which this material is used. It is hardly necessary to point out that we require to know the resistances of concrete when subjected to the stresses above mentioned, in designing concrete columns, walls, arches, and foundations.

Compressive strength of concrete.—It is usual to determine the compressive strength of concrete by subjecting cubes of the material to a compressive stress in the testing machine. The strength of a cube is greater than that of a square prism, the height of which is greater than the sides of the cube, and less than that of a prism the height of which is less than the side of the cube. In a paper on the Strength of Brickwork read before the Society in December 1900, the results were given of some experiments on the compressive strength of slabs and prisms of cement and lime mortar in which the sectional area was the same in each test, but the height varied from ½ an inch to 12 inches.

Professor Bauschinger has expressed the compressive strength of prisms of different heights of the same sectional area as follows:

$$\sigma = a + \beta \frac{\sqrt{f}}{l}$$

where σ denotes the compressive strength, f the sectional area, l the height of the prism, a and β constants to be determined by experiment. For prisms of dissimilar cross sections, he proposed the following formula:—

$$\sigma = (a + \beta \frac{\sqrt{f}}{l} \cdot \sqrt{\frac{4\sqrt{f}}{u}}$$

where u is the circumference of the cross section.

In order to ascertain the strength of concrete cubes of various proportions of cement, sand, and stone, it is necessary to prepare and test the specimens under conditions which are maintained as nearly uniform as possible throughout. Great care should be taken in the determination of the proportions of the various materials forming the concrete, and the quantity of water, so that every cube tested has actually the composition intended. This is accomplished by using the same cement throughout, also the same sand in which the sizes of the grains are restricted by two sieves of definite sizes, as for instance, passing the sand through a sieve of 400 meshes per square inch, and catching it on one of 900 meshes per square inch.

The broken stone used should be separated out into about three or four sizes by means of suitable screens or sieves and these afterwards mixed in the proportions intended. The quantity of water necessary should be separately determined for each kind of concrete, and this should be weighed out and mixed, when preparing the specimens in the correct proportion previously determined. The mixing should preferably be performed in a machine for the sake of better securing uniformity.

The concrete should be filled into metal moulds having plane and parallel faces, and carefully rammed—here also a machine similar to the Böhme hammer apparatus or lever press would be advantageous. The writer generally leaves the cubes in the moulds for 21 hours covered with damp cloths, and 3 hours out of the moulds before placing them in water.

The testing in a modern testing machine is comparatively a simple matter if the specimens have been accurately prepared, having parallel plane surfaces between the compression plates of the machine, the bottom one of which is provided with a ball bearing. The load is gradually increased until the specimen shews some signs of yielding, such as a hair crack; the load at this point

is noted, and afterwards increased until fracture occurs. The fractured cube has the form of a pyramid, the base of which is that of the cube, and nearly equal to it in height, the four corners of the cube are sheared away.

The following experiments were made by the writer on specimens 6 inch by 6 inch by 6 inch, the concrete was mixed and filled into the moulds by hand; the broken stone and the gravel used were separated into three sizes by means of screens, between 2 inch and 1 inch, between 1 inch and $\frac{1}{2}$ inch, and between $\frac{1}{2}$ inch and $\frac{1}{8}$ inch, these were then mixed together in the proportion of 5 : 2 : 1, and the volume of the voids carefully measured. It was found that the proportion of the voids in the broken stone was 39·5% and in the gravel 31·6%, so that sand was added to fill the voids in each case, and the cement was added in the proportion of 1 part of cement to 6, 8 and 10 of stone. The proportions of cement and sand entering into the composition of the mortars in the various concretes was therefore nearly as follows:—

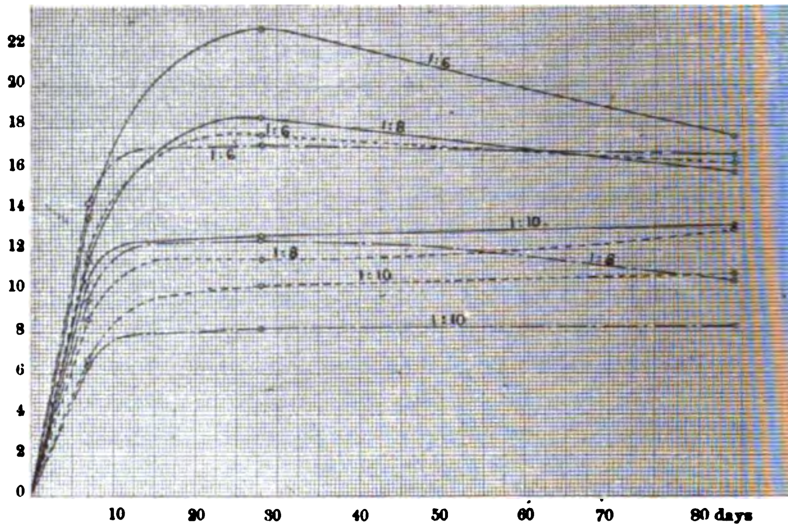
Broken stone concrete 1 to 2·4, 1 to 3·2, and 1 to 4
Gravel concrete 1 to 1·9, 1 to 2·5, and 1 to 3.

The gravel and blue metal (Basalt) was found to be practically non absorbent, but the sandstone absorbed 2·9% of water, so that more water was necessary to make sandstone concrete than in the case of gravel or blue metal. The results obtained by testing these cubes at 7 days, 28 days, and 84 days are recorded in the Table Series I. and plotted in figs. 1 to 3 inclusive.

A series of compressive tests were also made on cubes of concrete 12 inches by 12 inches by 12 inches prepared by ordinary workmen from concrete mixed in the usual way on the Sewerage Works, Arncliffe, near Sydney, and filled into timber moulds under instructions received from the Engineer-in-Chief for Sewerage Construction, Mr. J. Davis, M. Inst. C.E. The specimens were preserved in moist soil until they had reached the age required, then sent in carts to the Engineering Laboratory where they were tested. These specimens represent concrete made in the ordinary way, and were more or less rough, so that the uniformity so

COMPRESSIVE STRENGTH OF CONCRETE.—Series I.

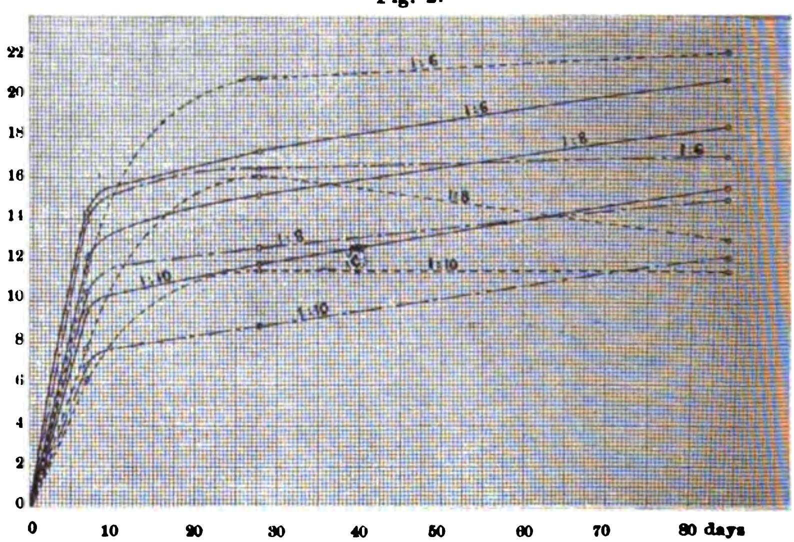
Fig. 1.



Abscissæ = Age in days. Ordinates = Crushing force in 100 lbs. per square inch. (Mean of two tests.)

Bluestone with bluestone dust ————
,, Nepean River sand — — — —
,, Sydney white sand

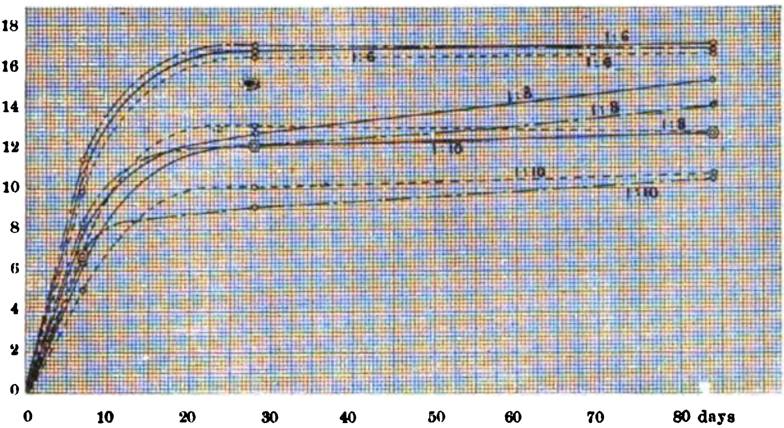
Fig. 2.



Abscissæ = Age in days. Ordinates = Crushing force in 100 lbs. per square inch. (Mean of two tests.)

Nepean River gravel with bluestone dust ————
,, ,, Nepean River sand — — — —
,, ,, Sydney white sand - - - - - - - -

Fig. 3.



Abscissæ = Age in days. Ordinates = Crushing force in 100 ℔s. per square inch. (Mean of two tests.)

Sandstone with bluestone dust ————

„ Nepean River sand – – – —

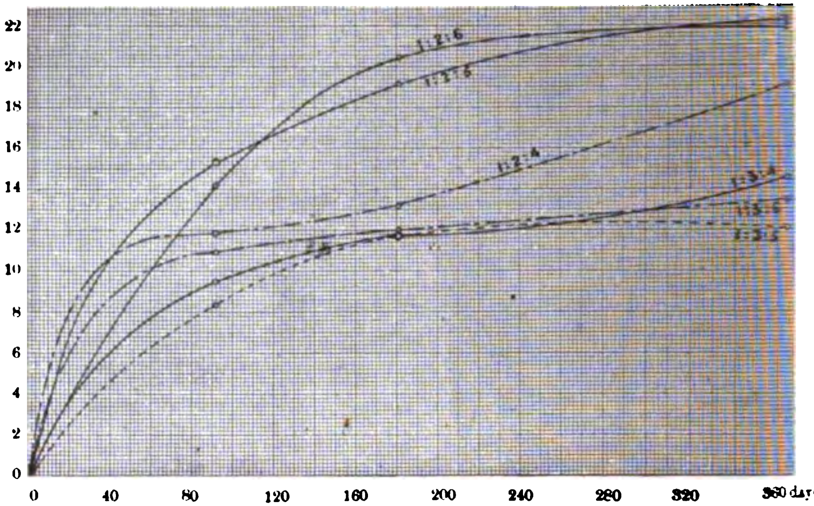
„ Sydney white sand - - - - - - - -

necessary for accurate results could not be obtained, the results are probably less than the actual strength of the concrete in the sewerage works at the age tested; they are recorded in the Table Series II., but the results have not been plotted as they were only tested at two ages.

A third series of tests were made on similar concrete prepared in a similar manner but filled into accurately made metal moulds forming cubes 6 inch by 6 inch by 6 inch, the results of these tests may be taken as representing fairly accurately the strength of concrete in the sewerage works, they are recorded in Table Series III., and plotted in figs. 4 to 8 inclusive, but they are in no sense laboratory tests as the concrete was made by ordinary workmen. Compression tests were also made on concrete prisms 3 feet high by 12 inch by 12 inch made as in Series II., the results of which are recorded in Table Series IV.

COMPRESSIVE STRENGTH OF CONCRETE.—Series III.

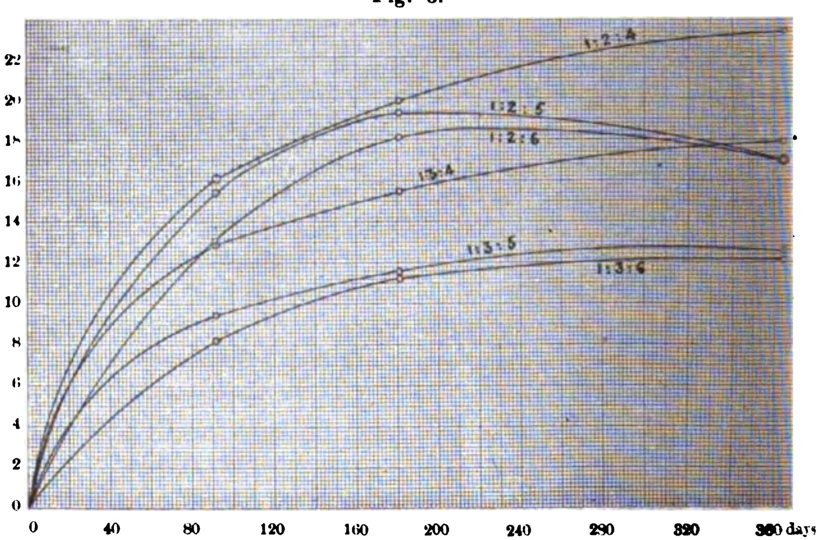
Fig. 4.



Abscissæ = Age in days. Ordinates = Crushing force in lbs. per square inch. (Mean of two tests.)

Cement, 'Tripod brand'; Nepean sand; bluestone, 2 inch gauge.

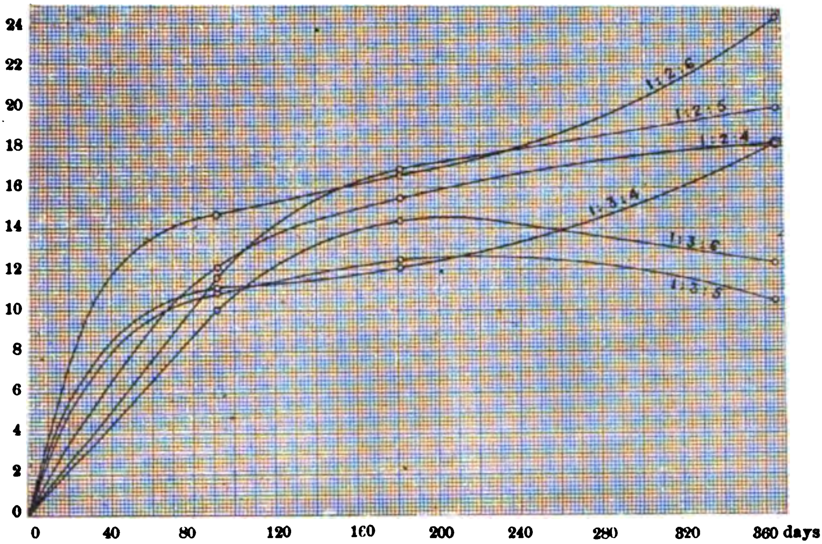
Fig. 5.



Abscissæ = Age in days. Ordinates = Crushing force in lbs. per square inch. (Mean of two tests.)

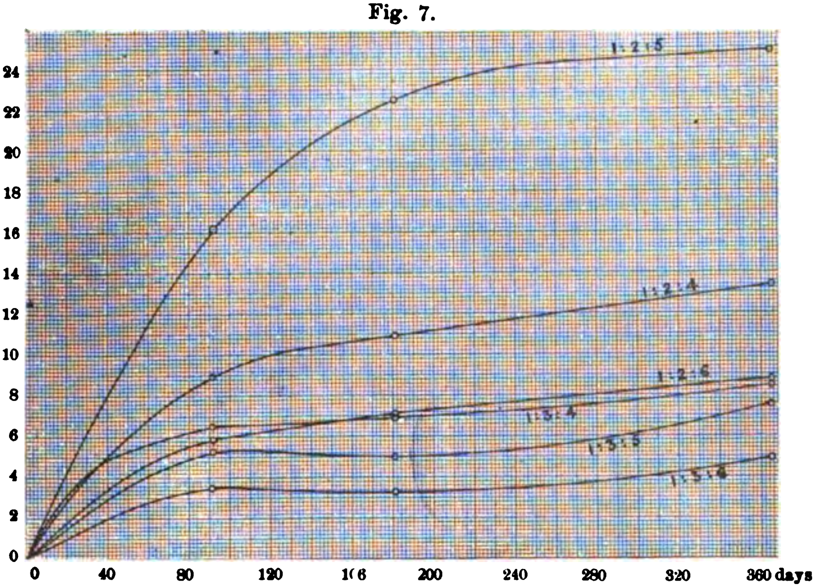
Cement, 'Tripod brand'; Nepean sand; sandstone 2½ inch gauge.

Fig. 6.



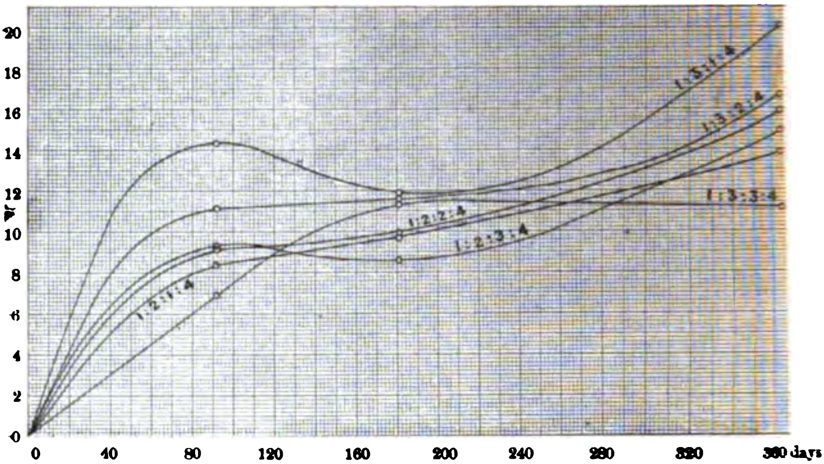
Absciss æ = Age in days. Ordinates = Crushing force in lbs. per square inch.
(Mean of two tests)
Cement, 'Tripod brand'; Nepean sand; sandstone 2 inch gauge.

Fig. 7.



Abscissæ = Age in days. Ordinates = Crushing force in 100 lbs. per sq. inch.
Cement, 'Tripod brand'; Nepean sand; pebbles 2½ inch gauge.

Fig. 8.



Abscissæ = Age in days. Ordinates = Crushing force in 100 lbs. per sq. inch. Cement, 'Tripod brand'; Nepean sand; screenings; bluestone 1½ inch gauge.

Transverse strength of concrete.—In making transverse tests of concrete, the beams were accurately supported on the end bearings and loaded in the centre, so that the beam was maintained in a horizontal position, having the three lines of contact of the end supports and central edge where the load was applied in true parallel planes. The beams were 3 feet long, 12 inches wide, and 12 inches deep, prepared by ordinary workmen by filling timber moulds in a similar manner to that described for the concrete cubes in Series II.

The beams were placed upon supports in the testing machine, 27 inches centre to centre and loaded in the centre. The results of these tests are recorded in Series V., and the modulus of rupture was calculated from the following formula :—

$$f = \tfrac{3}{2}\left(\frac{\left(\omega + \frac{\omega'}{2}\right) l}{b d^2}\right)$$

Where f = the modulus of rupture
ω = the breaking load applied at the centre
ω' = the weight of the beam between the centres of supports
b = the breadth
d = the depth
l = the span

Tensile strength of concrete.—The same concrete described in the foregoing tests was tested in tension: large size briquettes were prepared in which the proportions were the same as in the standard English and American briquettes used in cement testing, but the smallest section was 10 inches by 10 inches = 100 square inches. The accurate preparation of such large specimens by ordinary workmen in timber moulds, and the subsequent testing in the machine, was by no means an easy matter, and although they were tested carefully the results cannot be looked upon as representing the true tensile strength of the concrete in the work, as the nature of the process used in making the specimens must have rendered the results lower than would have been obtained on specimens prepared in the laboratory; they are recorded in Table Series VII.

Conclusions on the compressive strength of concrete.—Fig. 1 Series I., shows the compressive strength of bluestone concrete of three proportions with three kinds of sand, from which it is clear that bluestone dust is superior to either Nepean River sand or Sydney white sand, also the Sydney white sand comes out a little better than the river sand in this concrete, it will be observed that there is a fall in strength from 30 to 80 days, which would probably rise again at a later period, but the tests were not carried beyond the ages shown.

Fig. 2, Series I., shows the compressive strength of Nepean River gravel concrete of the same three proportions and the same three kinds of sand; here the Sydney white sand is best for the 6 to 1 and 8 to 1 concrete, but the bluestone dust is best in the 10 to 1 concrete, and in every case the Sydney white sand is better than the Nepean River sand.

Fig. 3, Series I., shows the compressive strength of sandstone concrete of the same three proportions, mixed with the same three sands, from which it will be seen that the effect of the sand is less than in Figs. 1 and 2, being about equal in the 6 to 1, and differing slightly in the others.

A series of tensile tests extending over 12 months, of the same cement mixed in the proportion of one part of cement to three of sand, showed that Nepean River sand was about the same strength as the Sydney white sand.

In this series of compressive tests recorded in tables and plotted in Figs. 1, 2, and 3, the mixing of the concrete in the proportions stated, the preparation of the cubes, and all the conditions of testing which could influence the results have been carefully attended to, so that they may be considered as laboratory tests. The cement used, however, is inferior to some of the best known brands to-day, which accounts for the results being rather low throughout.

Series II. were not plotted as they were only tested at two ages, but Series III., made from practically the same concrete, have been plotted in Figs. 4 to 8 inclusive. The concrete in both Series II. and III. was not made as carefully as in a laboratory, which has been already explained. It will be observed that the cement used was not the same throughout.

Fig. 4 shows the results of testing bluestone concrete 2 inch gauge and less, in which the proportions 1-2-5 and 1-2-6 give about the same strength in compression, whereas 1-2-4 is considerably lower, here the stronger concrete appears to be due to the greater proportion of stone to mortar. In the remaining curves 1-3-4, 1-3-5, and 1-3-6 the proportions of mortar to stone appears to make very little difference. In tests Nos. 1 to 6, Series II., the bluestone is 1½ gauge and the cement is different, the size of the cubes is 12 inches instead of 6, but in other respects the concrete is similar to that in Series III. recorded in Fig. 4, here also 1-2-5 is slightly better than 1-2-4, and 1-2-4 than 1-2-6, again 1-3-5 is better than 1-3-4 or 1-3-6.

Fig. 5, Series III., shows the compressive strength of sandstone concrete 2½ gauge, and Nos. 7 to 12, Series II., show also the strength of similar concrete in which the cement and the size of the cubes is different, but in other respects the conditions appear to be similar, excepting that the 12 inches by 12 inches cubes

were not made as carefully as the 6 inches by 6 inches. In Series II. the 1-2-6 concrete is better than 1-2-5 or 1-2-4, whereas in Series III. the 1-2-4 is better than either of the two others. The 1-3-4 is best in both series.

Fig. 6, Series III., and Nos. 13 to 18, Series II., show the compressive strength of sandstone concrete 2 inches gauge; here also the cements are not the same. The results show in both series that 1-2-6 concrete is the best, also compared age for age, as far as it is possible to make this comparison, since Series II., was not continued beyond 102 days, the same results are seen. In Fig. 6 the 1-3-4 concrete appears the best, and the diagram checks fairly well at 100 days with the results recorded in tests Nos. 13 to 18, Series II.

Fig. 7, Series III. and Nos. 19 to 24, Series II., do not agree at all, and the apparent differences in the conditions of the tests are not sufficient to account for the difference in the results.

Fig. 8, Series II., and Nos. 25 to 33 inclusive, do not represent concrete sufficiently similar to compare one with the other as in the foregoing cases.

In the tests of concrete prisms Series IV., the bluestone was broken to 1½ inch gauge, and the results Nos. 1 to 6 cannot be compared with Figs. 4 and 8, Series III., they are much more comparable with Nos. 1 to 6, Series II., from which it will be seen that Nos. 1 and 2 agree fairly well in giving the compressive strength from 87 to 100 tons per square foot, but Nos. 4, 5, and 6 do not agree; the remaining results are also irregular.

Conclusions on the transverse tests.—The results of these tests are recorded in the Table Series V., and any irregularity is due to the preparation of the concrete; the method of finishing the specimens in the moulds with true surfaces could not affect the results in transverse, as in the compressive tests. The greatest value of the modulus of rupture obtained was 312 pounds per square inch.

Conclusions on tensile tests.—From the nature of these tests and methods adopted, the results can only be regarded as a rough indication of the tensile strength of concrete, which is in every case below the real tensile strength.

Series I.—COMPRESSIVE STRENGTH OF CONCRETE CUBES, 6 inches by 6 inches.

No.	Description of concrete.	Proportion of stone to cement.	Percent. of water used in gauging.	Weight of concrete in lbs. per cube foot.	Force required to crack the cube in lbs. per sq. in.			Force required to crush the cube in lbs. per sq. in.		
					7 days old.	28 days old.	84 days old.	7 days old.	28 days old.	84 days old.
1	Blue metal sizes	6 – 1	5·55	148	833	1139	1083	1277	2277	1555
2	A. B. and C.,	„	„	„	925	1555	1166	1444	2305	1944
3	mixed in propor-	8 – 1	5·54	„	722	805	805	1222	1833	1555
4	tion of 5:2:1 with	„	„	„	527	1139	1166	1083	1916	1611
5	39·44% of blue-	10 – 1	5·31	„	500	750	500	1083	1361	1222
6	stone dust.	„	„	„	361	639	805	1028	1194	1416
7	Blue metal sizes	6 – 1	4·94	144	750	1111	805	1472	1750	1555
8	A. B. and C.,	„	„	„	889	1389	1000	1382	1694	1750
9	mixed in propor-	8 – 1	4·91	„	694	777	944	944	1166	1166
10	tion of 5:2:1 with	„	„	„	584	833	722	972	1333	944
11	39·44% Nepean	10 – 1	4·66	„	278	583	555	611	889	833
12	River sand.	„	„	„	278	555	416	666	750	833
13	Blue metal sizes	6 – 1	5·18	144	833	1194	1361	1166	1888	1694
14	A. B. and C.,	„	„	„	611	1000	694	1222	1633	1555
15	mixed in propor-	8 – 1	5·0	„	361	533	694	889	1166	1333
16	tion of 5:2:1 with	„	„	„	527	277	722	833	1166	1277
17	39·44% Sydney	10 – 1	4·92	„	444	388	666	639	888	944
18	white sand.	„	„	„	333	444	527	666	1166	1194
19	Nepean River	6 – 1	4·59	150	925	611	1500	1388	1722	2083
20	gravel, sizes D.	„	„	„	750	1083	666	1472	1750	2083
21	E. F. mixed in	8 – 1	4·41	„	555	555	694	1111	1555	1888
22	proportions of	„	„	„	722	555	722	1305	1500	1833
23	5:2:1 with 31·62%	10 – 1	4·18	„	500	277	444	944	1333	1388
24	bluestone dust.	„	„	„	277	250	777	972	1000	1722
25	Nepean River	6 – 1	4·11	150	972	1111	1111	1500	1527	1583
26	gravel, sizes D.	,	„	„	777	1583	888	1277	1777	1847
27	E. F. mixed in	8 – 1	4·06	„	611	694	972	972	1194	1639
28	proportions of	„	„	„	722	1055	777	1111	1333	1361
29	5:2:1 with 31·62%	10 – 1	3·97	„	416	750	889	611	925	1217
30	Nepean R sand.	„	„	„	333	611	750	777	833	1166
31	Nepean River	6 – 1	4·39	148	583	...	1250	1111	...	2277
32	gravel sizes D.	„	„	„	555	880	722	1388	2083	2139
33	E. F., mixed in	8 – 1	4·19	„	639	694	925	833	1639	1472
34	proportions of	„	„	„	472	750	472	722	1555	1111
35	5:2:1 with 31·62%	10 – 1	4·10	„	...	889	527	527	1194	1139
36	Sydney w. sand.	„	„	„	389	833	500	694	1139	1166
37	Broken sand-	6 – 1	8·42	136	722	1389	972	1111	1750	1722
38	stone sizes G.	„	„	„	361	1028	916	1027	1611	1694
39	H. I., mixed in	8 – 1	7·94	„	472	694	833	916	1250	1639
40	proportions of	„	„	„	277	861	722	666	1305	1527
41	5:2:1 with 39·44%	10 – 1	7·91	„	277	500	805	639	1222	1388
42	bluestone dust.	„	„	„	416	722	527	639	1194	1138
43	Broken sand-	6 – 1	7·78	134	777	1416	1277	1166	1777	1611
44	stone sizes G.	„	„	„	750	1194	1000	1111	1611	1777
45	H. I., mixed in	8 – 1	7·84	„	555	861	944	805	1277	1388
46	proportions of	„	„	„	639	777	888	861	1139	1416
47	5:2:1 with 39·44%	10 – 1	7·80	„	472	611	666	694	861	1027
48	Nepean R. sand.	„	„	„	361	694	583	639	944	1083
49	Broken sand-	6 – 1	7·84	134	666	1111	1138	1027	1611	1750
50	stone, sizes G.	„	„	„	500	1250	833	944	1666	1611
51	H. I., mixed in	8 – 1	7·89	„	444	972	888	666	1277	1250
52	proportions of	„	„	„	416	861	666	666	1305	1277
53	5:2:1 with 39·44%	10 – 1	7·85	„	277	666	694	500	1028	1083
54	Sydney w. sand.	„	„	„	277	750	583	500	1000	1083

Series II.—COMPRESSIVE STRENGTH OF CONCRETE CUBES, 12 inch by 12 inch. Mean of Three Tests.

No.	Description.	Proportions used in gauging.					Age in Days.	Cracked, tons per square foot.	Crushed, tons per square foot.	Age in Days.	Cracked, tons per square foot.	Crushed, tons per square foot.
		Cement.	Sand.	Screenings.	Stone.	Water.						
1	Cement, Red Cross brand. Sand, Nepean. Stone, bluestone, 1¼ inch gauge and downwards.	1	2	...	4	0·822	38	80·1	84·8	88	93·1	93·6
2		1	2	...	5	0·872	38	89·9	93·9	88	99·0	100·0
3		1	2	...	6	1·047	39	65·9	66·3	88	65·8	66·7
4		1	3	...	4	1·037	39	30 9	33·0	88	53 8	54·4
5		1	3	...	5	0·965	38	51·1	51·8	101	78 8	79·6
6		1	3	..	6	0·708	35	32·6	38·8	97	56 5	57·6
7	Cement, Red Cross brand. Sand, Nepean. Stone, sandstone, 2¼ inch gauge and downwards.	1	2	...	4	0·867	42	60·1	72·2	93	79·1	81·9
8		1	2	...	5	0 919	39	61·8	70·1	93	77·0	79·0
9		1	2	...	6	0·954	39	83·0	87·8	91	84·3	93·6
10		1	3	...	4	0·984	38	44·7	48·3	92	56·8	58·3
11		1	3	...	5	1·116	38	49·5	54·1	93	50·5	53·6
12		1	3	...	6	1·179	40	43·9	45·3	92	52 6	54·9
13	Cement, Globe brand. Sand, Nepean. Stone, sandstone, 2 inch gauge and downwards.	1	2	...	4	0·893	33	35·6	45·5	102	65·9	68·6
14		1	2	...	5	0·923	33	26·9	29·8	102	47·0	49·5
15		1	2	..	6	0·968	33	28·8	38·4	101	62·8	69·4
16		1	3	...	4	1·059	32	20·0	21·8	100	39·2	40·9
17		1	3	...	5	1·040	31	30·6	36·0	99	54·6	55·1
18		1	3	...	6	1·145	31	19·9	20·4	100	40·8	41·5
19	Cement, Red Cross brand. Sand, Nepean Stone, pebbles 2¼ inch gauge and downwards.	1	2	...	4	0·782	33	58·9	80·3	94	99·5	100·0
20		1	2	...	5	0·744	32	66·4	85·0	92	85 7	86·3
21		1	2	...	6	0·837	39	95·4	100·0	92	98 3	100·0
22		1	3	...	4	0 964	41	58·6	62·5	92	57·4	58·4
23		1	3	...	5	0·964	40	48·1	60·6	93	61·8	62·9
24		1	3	...	6	1·049	39	50·4	58·5	93	61·6	63·6
25	Cement, Red Cross braud. Sand, Nepean. Stone, bluestone, 1¼ inch gauge and downwards.	1	2	1	4	0·896	33	53·3	58·5	93	73·8	75 8
26		1	2	2	4	0·912	33	38·3	38 9	93	60·6	61·2
27		1	2	3	4	0·983	34	29·3	29·5	93	57·9	60·3
28	Cement, Globe brand. Toppings. Stone, bluestone, 1¼ inch gauge and downwards.	1	2	Top'ng 1	4	0·896	36 43	24·0 22·9	25·0 22·7	89	48·7	52·2
29		1	2	2	4	1·021	42 71	20·0 30·5	20·8 32·2	90	39·1	40·6
30		1	2	3	4	1·091	42 71	16·1 22·0	17·3 22·7	90	34·3	34·7
31	Cement, Globe brand. Sand, Nepean.	1	2	...	...	...	37 66	57·0 70·0	57·9 70·5	92	51·9	40·1
32		1	3	...	...	...	37 66	39·5 41·0	39·8 41·3	92	44·0	45·6
33		1	4	...	...	...	36 65	30·0 46·5	30·7 47·0	93	41·0	41·8

Series III.—COMPRESSION TESTS OF CONCRETE CUBES.

6 inches by 6 inches. Mean of Two Tests.

No	Description.	Proportions used in gauging: Cement	Sand	Screenings	Stone	Water	Force required to crush, tons per square foot: [illegible] days old	[illegible] days old	[illegible] days old	Force required [illegible] lbs. per square [illegible]: [illegible] days old	[illegible]	[illegible]
1	Cement, Tripod	1	2	..	4	0·910	75·96	84·62	122·75	1191·9	1316·[illegible]	[illegible]
2	brand.	1	2	...	5	0·910	98·50	122·77	143·90	1533·0	1916·[illegible]	[illegible]
3	Sand, Nepean.	1	2	...	6	1·010	90·[illegible]	131·53	140·70	1413·9	2047·[illegible]	[illegible]
4	Stone, bluestone	1	3		4	1·015	60·96	75·22	93·70	946·6	1170·0	[illegible]
5	2 inch gauge and	1	3	...	5	1·015	53·23	74·55	77·30	829·2	1170·0	[illegible]
6	downwards.	1	3	...	6	1·015	70·59	76·88	96·70	1098·6	1196·0	[illegible]
7	Cement, Tripod	1	2	...	4	1·000	103·61	128·30	149·3	1611·8	1995·0	[illegible]
8	brand.	1	2	...	5	1·000	99·55	123·97	109·00	1548·6	192[illegible]·5	[illegible]
9	Sand, Nepean.	1	2		6	1·000	83·84	116·43	109·00	1304·2	1811·5	[illegible]
10	Stone, sandstone	1	3		4	1·250	83·30	99·33	114·70	1295·8	1545·5	[illegible]
11	2¼ inch gauge	1	3		5	1·250	60·80	74·37	90·95	945·8	1157·0	[illegible]
12	and downwards.	1	3		6	1·500	52·94	72·05	77·85	823·6	1121·0	[illegible]
13	Cement, Tripod	1	2	..	4	1·000	75·27	97·23	116·85	1205·6	1547·5	[illegible]
14	brand.	1	2	...	5	1·000	74·91	108·64	127·70	1165·3	1691·5	[illegible]
15	Sand, Nepean.	1	2	..	6	1·000	94·11	107·05	156·10	1463·9	1662·5	[illegible]
16	Stone, sandstone	1	3	.	4	1·250	71·25	77·45	117·19	1108·5	1205·0	[illegible]
17	2 inch gauge and	1	3	...	5	1·250	69·91	80·71	67·70	1087·5	1255·5	[illegible]
18	downwards.	1	3		6	1·500	64·33	92·55	85·70	1000·7	1440·0	[illegible]
19	Cement, Tripod	1	2	..	4	0·965	57·59	70·62	86·40	895·8	1098·5	1344·[illegible]
20	brand.	1	2	...	5	1·002	104·23	124·99	159·55	1622·2	2255·0	[illegible]
21	Sand, Nepean.	1	2	..	6	1·100	38·03	36·65	56·40	591·6	709·0	[illegible]
22	Stone, pebbles, 2¼	1	3	...	4	1·203	42·14	44·95	54·95	655·5	699·0	[illegible]
23	inch gauge and	1	3		5	1·337	33·94	32·76	48·45	527·0	503·0	[illegible]
24	downwards.	1	3	...	6	1·434	22·45	21·60	31·85	349·3	335·0	[illegible]
25	Cement, Tripod	1	2	1	4	1·040	54·01	62·41	89·50	840·3	971·0	[illegible]
26	brand.	1	2	2	4	1·250	58·48	62·74	102·35	909·7	984·0	[illegible]
27	Sand, Nepean.	1	2	3	4	1·400	60·18	55·80	96·40	936·1	866·0	[illegible]
28	Stone, bluestone	1	3	1	4	1·029	91·96	75·27	129·00	1430·6	1184·0	[illegible]
29	1¼ inch gauge	1	3	2	4	1·156	72·94	74·11	107·50	1134·7	1153·0	1672·2
30	and downwards.	1	3	3	4	1·368	44·86	72·83	71·55	697·9	1144·0	1113·4
31	Cement, Tripod	1	2	...	...	...	71·39	65·22	88·40	1110·5	1015·5	1375·0
32	brand.	1	3	...	...	...	79·02	58·35	98·55	1228·8	908·0	1532·6
33	Sand, Nepean.	1	4	...		..	52·54	54·87	47·85	782·6	858·0	744·4

Series IV.—COMPRESSIVE TESTS OF CONCRETE COLUMNS, 3 feet long by 12 inches by 12 inches.

No.	Description.	Proportions used in gauging.					Weight per cube foot.	Age in days.	Cracked at tons per square foot.	Crushed at tons per square foot.
		Cement.	Sand.	Screenings.	Stone.	Water.				
1	Cement, Globe brand	1	2	.	4	0·943	141	113	92·0	92·3
2	Sand, Nepean.	1	2	...	5	1·079	147	112	87·0	87·0
3	Stone, bluestone, 1½									
4	gauge and down-	1	3	...	4	1·050	136	110	52·0	52·1
5	wards.	1	3	...	5	1·245	135	109	33·0	33·1
6		1	3	...	6	1·243	134	94	19·5	20·8
7	Cement, Globe brand	1	2	...	4	0·983	128	107	44·5	45·1
8	Sand, Nepean.	1	2	...	5	1·079	133	106	72·7	73·3
9	Stone, sandstone, 2½	1	2	...	6	1·103	129	108	44·0	46·7
10	gauge and down-	1	3	...	4	1·088	127	107	54·0	54·8
11	wards.	1	3	...	5	1·237	130	106	37·0	37·5
12		1	3	...	6	1·310	132	104	46·0	46·9
13	Cement, Globe and	1	2	...	4	0·983	134	103	52·5	53·0
14	Tripod brands.	1	2	...	5	1·127	133	102	68·0	68·8
15	Sand, Nepean.	1	2	...	6	1·210	128	102	34·0	34·7
16	Stone, sandstone 2	1	3	...	4	1·190	131	98	31·0	31·3
17	inch gauge and	1	3	...	5	1·471	129	98	28·0	29·3
18	downwards.	1	3	...	6	1·500	133	99	34·4	34·1
19	Cement, Tripod brand	1	2	...	4	0·965	138	92	51·0	51·9
20	Sand, Nepean.	1	2	...	5	1·002	141	92	91·5	92·0
21	Stone, pebbles 2½	1	2	...	6	1·000	136	92	34·5	35·0
22	inch and down-	1	3	...	4	1·203	133	92	24·7	29·7
23	wards.	1	3	...	5	1·337	142	92	30·0	31·0
24		1	3	...	6	1·434	129	92	17·0	17·2
25	Cement, Tripod brand	1	2	1	4	1·040	146	98	49·0	49·8
26	Sand, Nepean.	1	2	2	4	1·250	142	97	50·0	50·7
27	Stone, bluestone 1½	1	2	3	4	1·400	144	96	48·0	48·3
28	inch gauge.	1	3	1	4	1·029	142	95	64·0	64·9
29		1	3	2	4	1·156	141	92	67·7	68·2
30		1	3	3	4	1·368	140	92	46·0	46·8
31	Cement, Tripod brand	1	2	...	...	0·603	127	92	63·0	63·7
32	Sand, Nepean.	1	3	...	...	0·674	126	92	50·5	55·5
33		1	4	...		0·751	120	92	32·0	32·9

Series V.—TRANSVERSE TESTS OF CONCRETE BEAMS, 3 feet by 12 inches by 12 inches.

Mean of Two Tests.

No.	Description.	Proportions used in gauging.					Age in days.	Weight per cube foot lbs.	Breaking weight in lbs.	Modulus of rupture lbs. per sq. inch.	Age in days.	Weight per cube foot lbs.	Breaking weight in lbs.	Modulus of rupture lbs. per sq. inch.
		Cement	Sand.	Screenings.	Stone	Water.								
1	Cement, Red Cross brand	1	2	...	4	0·822	41	139	8489	225	101	140	11200	296
2	Sand, Nepean	1	2	..	5	0·872	41	141	11804	312	101	140	11222	296
3	Stone, bluestone, 2¼ inch gauge	1	2	...	6	1·047	42	138	7336	185	100	141	10102	267
4	and downwards	1	3	...	4	1·037	42	137	4592	124	100	141	5756	154
5		1	3	...	5	0·965	41	139	7560	201	99	141	10147	268
6		1	3	...	6	0·708	38	134	5476	147	97	142	7298	211
7	Cement, Red Cross brand	1	2	...	4	0·867	35	134	6205	166	104	134	6809	181
8	Sand, Nepean	1	2	...	5	0·919	32	132	5275	142	101	134	7100	189
9	Stone, sandstone, 2¼ inch gauge	1	2	...	6	0·954	32	132	6585	176	101	134	8960	237
10	and downwards	1	3	...	4	0·984	32	130	5253	141	100	134	6093	163
11		1	3	...	5	1·116	32	121	5286	142	100	134	7638	203
12		1	3	...	6	1·179	31	122	5163	138	99	134	8066	214
13	Cement, Globe brand	1	2	...	4	0·893	38	125	4995	134	96	132	6653	177
14	Sand, Nepean	1	2	...	5	0·923	38	126	4592	123	96	131	5531	148
15	Stone, sandstone, 2 inch gauge	1	2	...	6	0·968	37	131	5320	142	95	127	5667	151
16	and downwards	1	3	...	4	1·059	37	128	3248	88	94	127	5622	150
17		1	3	...	5	1·040	37	126	4132	111	94	131	6317	168
18		1	3	...	6	1·145	36	126	3360	92	94	131	6272	167
19	Cement, Red Cross brand	1	2	...	4	0·782	37	136	5387	145				
20	Sand, Nepean	1	2	...	5	0·744	38	148	6686	179				
21	Stone, pebbles, 2¼ inch gauge	1	2	...	6	0·837	38	149	7672	204				
22	and downwards	1	3	...	4	0·964	37	139	7078	189				
23		1	3	...	5	0·964	36	148	5533	149				
24		1	3	...	6	1·049	35	138	4625	125				
25	Cement, Red Cross brand	1	2	1	4	0·896	33	132	9363	248	92	146	12566	332
26	Sand, Nepean. Stone, bluestone	1	2	2	4	0·912	33	133	7368	198	92	146	10909	289
27	1½ inch gauge and downwards	1	2	3	4	0·983	33	137	7448	198	91	146	10528	279
				Top'ngs										
28	Cement, Globe brand	1	2	1	4	0·896	44	132	6417	173	91	140	8960	238
29	Sand, Nepean. Stone, bluestone	1	2	2	4	1·021	43	118	5806	154	90	142	7504	200
30	1½ inch gauge and downwards	1	2	3	4	1·091	43	118	2934	80	90	142	6317	169
31	Cement, Globe brand	1	2	...	...	...	38	121	7640	203	92	119	6000	150
32	Sand, Nepean	1	3	...	...	...	38	120	6630	176	92	119	5555	148
33		1	4	..	..	...	38	120	4424	119	91	117	5210	140

Series VI.—COKE CONCRETE.

No.	Description.	Proportions used in gauging. Cement.	Small coke.	Large coke.	Weight per cubic foot in lbs	Breaking weight in lbs.	Modulus of rupture.
1	12 inch by 12 inch by 48 inches	1	4	2	69	7772	204
2	ditto	1	4	2	67	7884	206
3	ditto	1	4	2	65	7562	198
4	ditto	1	3	3	67	7168	188
5	ditto	1	3	3	69	7806	205
6	ditto	1	3	3	66	7840	206
7	9 inch by 9 inch by 48 inches	1	4	2	73	4133	257
8	ditto	1	4	2	72	3481	217
9	ditto	1	4	2	75	4458	278

Series VII.—TENSILE TESTS OF CONCRETE BRIQUETTES.
Mean of Three Tests.

No.	Description.	Proportions used in gauging. Cement.	Sand.	Screenings.	Stone.	Water.	Age in days.	Breaking load in lbs. per sq. inch.	Age in days.	Breaking load in lbs. per sq. inch.
1	Cement, Globe	1	2	...	4	0·943	66	116·9	94	162·3
2	brand	1	2	...	5	1·079	65	59·6	190	102·5
3	Sand, Nepean	1	2	...	6	1·063	64	42·2	190	76·2
4	Stone, bluestone,	1	3	...	4	1·050	63	25·3	190	70·1
5	1¼ inch gauge	1	3	...	5	1·245	64	34·7	190	41·3
6		1	3	...	6	1·243	64	35·9	190	63·8
7	Cement, Globe	1	2	...	4	0·983	64	28·6	183	33·3
8	brand	1	2	...	5	1·079	63	72·4	183	94·5
9	Sand, Nepean	1	2	...	6	1·103	63	50·8	183	92·5
10	Stone, sandstone	1	3	...	4	1·088	62	44·4	183	71·4
11	2¼ inch gauge	1	3	...	5	1·237	61	39·7	185	69·9
12	and downwards	1	3	...	6	1·310	61	36·3	183	37·4
13	Cement, Globe	1	2	...	4	0·983	59	64·0	183	113·2
14	brand	1	2	...	5	1·127	58	75·4	182	102·3
15	Sand, Nepean	1	2	...	6	1·210	58	63·7	182	86·0
16	Stone, sandstone	1	3	...	4	1·190	61	59·9	182	88·9
17	2 inch gauge	1	3	...	5	1·471	61	72·0	182	104·2
18	and downwards	1	3	..	6	1·500	63	61·5	182	81·2
19	Cement, Tripod	1	2	...	4	0·965	41	54·1	181	129·6
20	brand	1	2	...	5	1·002	40	65·5	181	95·9
21	Sand, Nepean	1	2	...	6	1·100	36	41·3	181	74·8
22	Stone, pebbles 2¼	1	3	...	4	1·203	36	44·3	181	57·2
23	inch gauge and	1	3	...	5	1·337	36	27·5	181	61·7
24	downwards	1	3	...	6	1·434	34	36·6	181	71·3
25	Cement, Tripod	1	2	1	4	1·040	59	109·1	182	148·9
26	brand	1	2	2	4	1·250	58	75·6	182	124·9
27	Sand, Nepean	1	2	3	4	1·400	55	90·7	182	112·5
28	Stone, bluestone	1	2	1	4	1·029	59	94·2	181	166·8
29	1¼ inch gauge	1	2	2	4	1·156	60	100·6	181	125·2
30	and downwards	1	2	3	4	1·368	58	74·8	181	110·2
31	Cement, Tripod	1	2	...	...	0·603	57	110·3	181	170·3
32	brand	1	3	...	...	0·674	56	99·1	181	138·6
33	Sand, Nepean	1	4	...	...	0·751	55	72·0	181	92·6

NOTES ON THE UNDERGROUND WORKINGS OF A COLLIERY IN THE WESTERN COALFIELDS OF NEW SOUTH WALES.

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[*Read before the Engineering Section of the Royal Society of N. S. Wales, September 18th, 1901.*]

As I am led to believe that the question of coal-mining viewed from an Engineer's standpoint has never come before this Society, I thought that a few notes, taken at different times in a Western Colliery, might be of some interest, especially in view of the vast importance of the industry to the welfare of the State, and the enormous development that must take place in the near future. The magnitude of the industry may be judged from the following figures:—The total output of coal from New South Wales for the year 1899 amounted to 4,597,028 tons valued at £1,325,799 and the total output since the year 1829 amounts to 85,969,136 tons valued at £35,647,004. The increased annual value of the coal mined for 1899 was £53,967, and for 1900 it was £343,112. The industry gives direct employment to 10,339 persons, and indirect employment to many others.

It has been pointed out that so far we have touched only the fringe of our coal supplies, and that there is in view enough coal to last for a century even at the present large output; the enormous and apparently inexhaustible wealth of our coal measures has, it may be feared, led to some prodigality in the method of exploiting them, but in this respect, as well as many others, we are trustees for posterity, and it is our duty to adopt those improved methods that the development of engineering has placed at our disposal in order to make an economical use of our great heritage.

As the possession of coal means wealth and power to the country that possesses it, the man who can make a lb. of coal go as far or

do as much work as 2 lbs. does at the present time, or who can get one ton of good round coal for every half ton now obtainable out of a seam by improved engineering methods, is a benefactor to his country. These notes were taken at the Zig Zag Colliery near Lithgow, the second of importance in the Western District, and as this colliery may be termed a typical one, the notes as to the general methods of working will apply to the whole district.

The output of coal for the Western District for the year 1899 was 217,817 tons, valued at £45,455, or nearly one-twentieth of the whole output of the State for the same year, and it employed 403 persons. The output for the Zig Zag mine for the same year was 29,897 tons, employing 39 hands, but this year the output bids fair to reach 60 or 70,000 tons.

This mine was originally the property of that enterprising and far-seeing man the late Mr. Thomas Sutcliffe Mort, who acquired the land partly by purchase from the Crown and partly from private landowners, but his lamented death occurred before he had an opportunity of practically testing its value. The property still remains in the hands of the family, and is leased to Mr. Thomas Saywell.

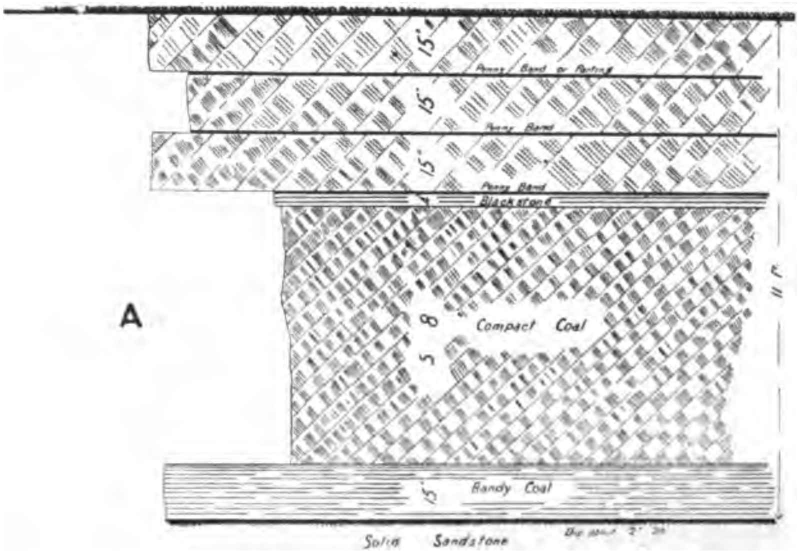
Description of Seam.—The seam is known as the Lithgow Seam and is 11 feet thick, and consists of—(1) 15 inches of bandy coal on a floor of sandstone. (2) 5 feet 8 inches of compact coal. (3) 4 inch of blackstone. (4) Three plies or layers of top coal or tops, averaging in thickness 15 inches each and parted by penny bands of stone.

Diagram A.

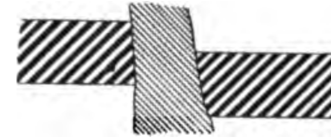
The roof is of solid sandstone and very strong. The seam dips about 2° 20′ in a direction about N. 60° E., but owing to the absence of any survey in the vertical plane the exact slope of the dip is unknown.

The 5 feet 8 inches compact coal in the seam is of a good bituminous quality, its colour is a dull black, and it is excellently adapted for steam purposes; at present this is the only part of

A



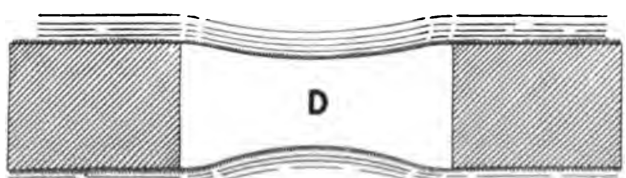
B



Down throw

C

Roll



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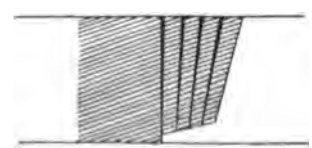


C

Greyback

the seam that is mined, except in the levels and roadways where the coal is taken out to the full height of the seam.

The tops are very friable, and if worked would produce a large quantity of slack, probably 50%, which with extra labour for picking out the partings and other impurities, renders them unpayable at present. Taking the seam all through the coal is remarkably clean; there are very few faults, and they are of an unimportant character; the latter consist of sandstone dykes but they seldom cause any throw in the seam; an exceptional case was one which I examined in No. 3 District, causing a downthrow of one foot. (Diagram B.)

A few 'rolls' and 'greybacks' intrude into the seam, and occasionally make a good deal of dead work; the former consist sometimes of hard and sometimes of soft stone, but in every case they make the coal very curly for some yards around them, the latter are designated 'greybacks' from their colour. (Diagram C.)

The experience gained in working the seam so far proves the coal to be remarkably free from gas and no safety lamps are used in the pit. The coal in the seam is very easily worked probably due to its well defined planes of cleavage, which with a few deviations, run in a northerly direction, and a miner will get more coal in this colliery in one day than in many others, as the following figures demonstrate, and this is typical of the whole Western District. The average amount of coal raised in the State in 1899 per miner was 564 tons; in the Western District 656 tons; and in the Zig Zag Mine 854 tons. The coal is mined by holing or undercutting and shearing, and falls away from the tops of its own weight, no blasting or explosives being necessary.

An analysis of the coal taken from the upper part of the seam is as follows:—

Water	2·24
Volatile hydrocarbon	29·09
Fixed carbon	56·06
Ash	11·78
Sulphur	0·83
Total	100·00

The specific gravity is 1·329. One pound of this coal will convert 12 pounds of water into steam.

Coke making was tried some years ago but with unsatisfactory results, it requiring 3 tons of coal to make 1 ton of coke. The seam is reached by a vertical shaft, 14 feet by 7 feet and 200 feet deep, through which all coal is drawn, and there is a ventilating shaft 8 feet diameter, about 375 yards distant from the hauling shaft; the cages in the shaft are single deck and fitted to hold two skips. At the bottom of the shaft there is a Blake pump which is capable of lifting 40,000 gallons of water in 24 hours, and it generally runs about 4 hours a day to keep the mine dry. In the dip there is one of Evans' hydraulic pumps connected to the Lithgow Water Supply, giving a head of 385 feet, or about 170 lbs. pressure; the diameter of the supply cylinder is 3 inches, connected to a supply pipe 1¼ inch diameter, and the diameter of the pump cylinder is 5 inches with a discharge pipe 4 inches diameter and 418 yards long, the length of stroke is 12 inches, and the number of strokes is 26 per minute; the pump is estimated to deliver 15,000 gallons a day, but two or three hours pumping a day is sufficient to keep the workings dry. It is a very handy pump for a low lift, and has few working parts to get out of order, it can be started at the surface or in the pit as convenient. The ventilation of the colliery is effected by a furnace at the bottom of the ventilating (or air) shaft, and the quantity of air circulating through the workings is 33,000 cubic feet per minute.

System of Working.—The system of working adopted in this mine and generally through the Western District is that known as the 'pillar' and 'stall.' In the greater part of the broken mine the bords were driven 5 feet 8 inches high, or just the height of the compact coal, and from 4 to 5 yards wide with pillars of the same dimensions, later on the bords were widened first to 8 yards and then to 12 yards, but the size of the pillars was not increased. These dimensions for pillars are totally insufficient for the due preservation of the broken mine and render it very susceptible to 'thrust' and 'creep': the pressure of the roof splits up the pillars

and even if they are not altogether crushed, a large proportion is ground into small coal; if the floor is weak the downward pressure of the roof upon these small pillars causes the floor to rise between them as illustrated in diagram D., now however an improved system has been adopted in which 12-yard bords and pillars predominate.

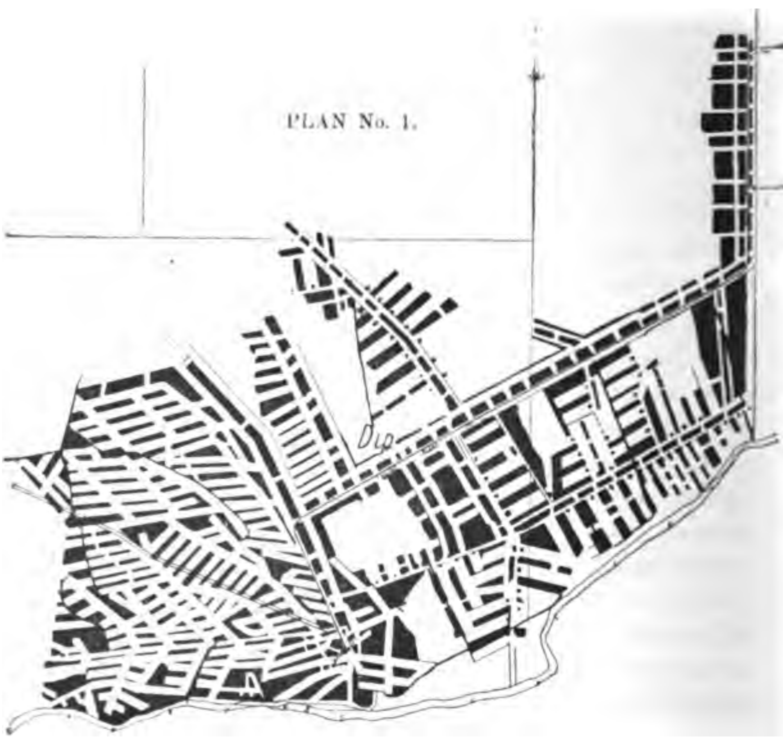
The 'creep' is to be much dreaded, and having once set in it spreads slowly but surely over the whole mine, no timbering can arrest its progress, roadways and airways require constant and costly repairs, and it is often so severe in its effects as to necessitate the abandonment of the district or mine. Much damage has already occurred owing to the deficiency of pillars, and over a large area pillars have been crushed and tops have fallen.

In addition to the danger caused by narrow pillars there is the great loss of coal when the pillars are being removed; if the pillar is too small it cannot carry the pressure of the roof without having its sides and ends split and fractured, so that the working of the pillar results in an abnormal quantity of slack. In small pillars it is generally estimated that only 50% of the coal can be extracted, but in large pillars 80% can generally be relied upon; in narrow bords the proportion of waste is considerably more than in wider bords, so that the wider the bord and pillar the more economical is the working, this is seen in diagram E.

This view as to the size of the pillars is corroborated by the Chief Inspector of Coal Mines in his report for the year 1899, where the following remarks occur:—"The pillars left in the bord and pillar system still continue to be made too small at some of the collieries in the first instance, having regard to a successful "broken" or second working and also to the extraction of the greatest possible percentage of coal from a given area. It is a difficult matter to persuade some colliery managers of the unsuitability of the time honoured 8 yard bord and 8 yard pillar even under very much increased depth. The following condition bearing on this point is now included in the leases which are issued for working coal under Crown lands. The percentage of coal to

be left in the pillars after the bords, headings, and drives are constructed shall be as follows:—"Where the depth from the surface does not exceed 200 feet 50%, from 200 to 500 feet in the proportion of 50 to 60%, from 500 to 1,000 feet in the proportion of 60 to 70%, etc."

There is no doubt that in this mine and many others there are large areas of broken mine, the second working of which (that is the pillar working) cannot be successful owing to the extravagant method of robbing the pillars and working easy coal: in the older workings of the mine the proportion of pillars to the whole seam is only 37%. In the Zig Zag colliery the depth is from 200 to 300 feet, so that the new rules for the size of pillars are unwittingly very nearly the same as the Chief Inspector advises. Plan No. 1 shews a portion of the workings more particularly the dip, where



coal-mining is now in progress, it also shews the engine plane, shafts, etc.

Whether the pillar and stall system of working the coal in this colliery is the best or not is open to discussion, and a few descriptive remarks on the general methods of laying out underground workings may be of interest. First it may be stated that the great object to be kept in view in all coalmining is the obtaining of the greatest quantity of coal, in the best condition and with the least expenditure of money; and in order to attain that end the system to be adopted is a question of great importance, and one deserving the careful consideration of the Engineer.

Generally speaking there are two systems, but they have modifications, one being known as the "Pillar and Stall" and the other as the "Long Wall," both systems have their respective advocates, and their relative merits are a favourite subject of dispute, something like the Telford and McAdam systems of roadmaking or the battle of the railway gauges, but they each have peculiar advantages under certain circumstances.

In the pillar and stall system, excavations called bords are driven through the coal parallel to one another and at certain intervals apart, so as to leave a rib of coal between them to support the roof; the excavations are made as wide as the strength of the roof will permit. At right angles to these, another set of excavations are driven parallel to one another and narrower than the bords; the sets of excavations crossing one another leaves in the seam rectangular blocks of coal called pillars.

Now coal is divided into cubes by joints or cleavage planes running perpendicularly to one another, the most defined joint is called the "cleat" and its surface is called the "face" in opposition to the least defined plane which is called the "back or end" and in pillar and stall working the bords are driven at right angles to the cleat so as to obtain the advantage of the pressure of the roof which tends to cleave the coal on the principal planes of cleavage, that is to say, the seam has a tendency to break up under the

action of the descending roof into slabs thus, see diagram F, and when the face is undercut or holed the pressure of the roof added to the weight of the unsupported coal tends to produce the fracture of the coal along the lines of cleavage and to save labour and hewing; thus enabling the produce of the seam to be obtained at the least possible cost.

In long wall working the whole of the coal is removed in a long and continuous face, which is called the wall-face. A stall is that portion of the wall-face kept in advance of those behind them, and in which a gang of miners work. The length of the stalls vary from 10 up to 50 yards, or even longer; the length depends upon the strength of the coal and the roof, if the latter are strong the stalls may be made long. If the face is made too long the roof has a tendency to break along the line of the wall-face which may become dangerous, hence it is the practice to break the line of face up into stalls, one in advance of the other.

The question of roads to the stalls is one of difficulty, and the expense of keeping up numerous roads has to be avoided if possible and this frequently governs the length of the stalls. The wall-face may be laid out parallel to the cleat or as for the workings to advance at right angles to the cleat, or the wall-face may be laid out perpendicular to the cleat so that the working advances on the ends, or it may be laid out as what is called "half on" or with the face at 45 degrees with the cleavage planes. In the first as has been shown, the mineral is "gotten" more easily and the labour reduced to a minimum, and the produce of the seam is obtained at the least possible cost, but if the coal is weak and tender it will be at a great sacrifice of physical condition and there will be a great increase of waste and small coal in the getting, the breaking up, and the loading. In the second method, the coal is in a better position to resist the crushing effect of the descent of the roof, consequently the coal will be obtained in a better condition but at a greater cost; therefore in strong seams it is usual to lay out the wall-face parallel to the cleat for the working to advance across it, and in tender seams to lay out the wall-face

perpendicular to the cleat so that the working may progress end on. The third method of "half on" or the laying of the wall face at an angle of 45 degrees to the cleat is adopted in only moderately strong seams as a compromise between the other two, so that advantage may be taken of the influence of the cleavage planes in order to secure the greatest quantity of coal in the best condition with the least labour. The long-wall system possesses the important advantage of giving the greatest quantity of coal because all the seam is extracted, whereas in the pillar and stall system a portion of the pillar is always lost, but as a rule it entails more initial outlay for roads and yardage work; it also gives the greatest amount of large coal, because in the narrower workings of the other system the coal must necessarily be more broken up. Another advantage of this system is that the ventilation is simple and more easily effected and the miner works in better air and in larger room and his labour is more efficient.

On the other hand there are circumstances which may render it absolutely necessary to adopt the pillar and stall system, for instance the long-wall in some cases requires a great deal of rubbish or stone for packing the "gob" behind the workmen to take the weight of the descending roof so as to prevent damage to the surface, and the packing may be difficult or costly to obtain. In this coalfield, and I believe in all the coalfields of New South Wales, the long-wall system has never had a fair trial in spite of its manifest advantages, but whether this is due to prejudice or to some other tangible objection such as the cost of filling the "gob," with the existing high rate of wages I have never been able to determine. Diagram G. illustrates an ideal form of pillar and stall setting out, and Diagram H. illustrates the system of long-wall working.

Haulage.—Until lately the haulage was done by horses, the skips being drawn out of the working places to a flat in the heading or main road where they were made up into trains and drawn thence to the shaft, but this slow and expensive system has partly given way to steam haulage. Now there is a steam hauling engine

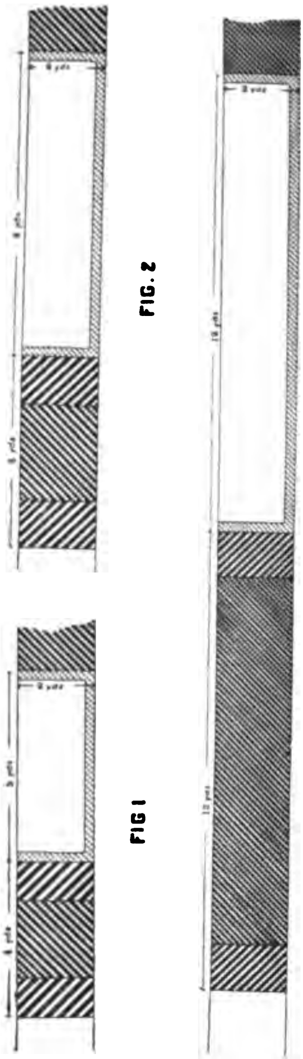
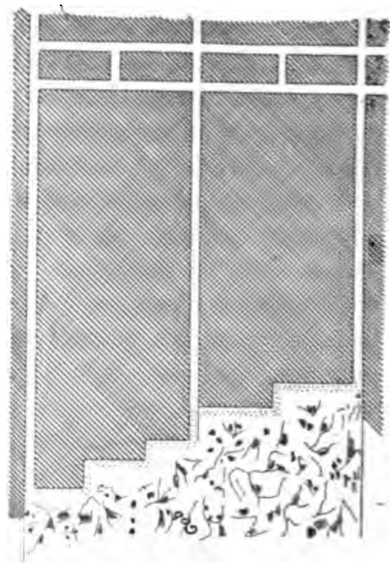


FIG 1

FIG. 2

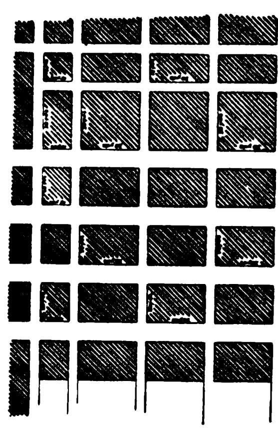
FIG 3

E



H

SYSTEM OF LONG WALL



C

IDEAL FORM OF PILLAR ... STALL SETTING OUT

at the bottom of the shaft which draws from the dip workings a total distance of 45 chains; at 17 chains from the shaft there is a flat for making up trains of skips drawn from the other workings

by horses. The system of haulage is known as the main and tail rope.

The engine is one of Tangye's 28 h.p. and is supplied with steam from boilers on the surface, it has two coupled cylinders, diameter 12 inches, length of stroke 18 inches, the usual speed is about 200 strokes per minute, and the ratio of the piston to the spur wheel is 1 to 3¼. There are two drums of 54 inches diameter, and they will hold about 2,500 lineal yards of 2 inch rope weighing 4 ℔s. to the fathom; the drums one for the main rope and one for the tail rope are fitted with clutches and can be thrown in or out of gear as required, and have separate brakes. The engine plane or road has a grade of about 1 in 60, and is laid with 20℔ rails to a gauge of 2 feet 1 inch. Rollers for carrying rope are made of steel, main rollers 6 inches diameter, tail sheaves 8 inches diameter, distance apart about 20 feet: sheaves at curves about 3 feet diameter, return wheel at end of plane 5 feet diameter. The main rope draws out the full skips and the tail rope takes back the empties, when the full skips are being drawn out the tail rope drum runs loose on the shaft: when the tail rope is hauling in the empties the main rope drum is thrown out of gear. The total length of the main rope on the plane is about 1,000 yards, and the tail rope 2,000 yards.

The main rope passes off the drum under a pully into the axis of the road and is attached to the fore end of the first skip, the tail rope is carried along near the roof at the side of the road around a sheave at the end of the plane and attached to the hinder end of the last skip of the train. A train consists of 30 skips, and each skip carries 19 cwt., the skip alone weighing 6¾ cwt. The time required for a trip out or a trip in is 5 minutes. There is an elevated siding or kip near the shaft up which the full skips are drawn by the rope to stand until they are wanted, from whence they are easily run down by hand on to the cage in the shaft to be taken to the surface; the empties that come down the shaft are pulled out of the cage by hand and run by gravitation to the main plane and made up into trains for return to the workings;

there are sidings and flats at convenient places for taking up skips from other parts of the workings. The engine plane is lighted with electricity by incandescent lamps, the dynamo and engine being in the engine room on the surface.

As may be readily understood the conveyance of the produce of the seam to the shaft constitutes a very important question for the Engineer in order that he may achieve that part of the ultimate object of coal mining, "the obtaining of the largest amount of coal in the best condition, and also at the least possible cost." He has to consider the best and most economical system of haulage for the particular seam he is dealing with: the class of road he should adopt, and when laid, its maintenance in a state of efficiency, the inclination, the curves, the size and form of the skip, the dimensions of the wheels and axles, and whether the skips shall be of iron or wood, and so on: all these things have a very important bearing on the working of a colliery successfully; but the various systems of underground traction would require a separate paper and I fear I have already trespassed too long on your patience. I have only touched lightly upon some of the aspects of coal-mining in this district, because it would be manifestly impossible within the limits of a paper to deal exhaustively with such a large subject as the underground workings of a colliery.

SYDNEY SEWERAGE: TESTING STONEWARE PIPES USED IN RETICULATION SEWERS.

By W. E. Cook, M.C.E., M. Inst. C.E.

[Read before the Engineering Section of the Royal Society of N. S. Wales, December 18th, 1901.]

Before describing the method of testing the stoneware pipes used in the reticulation sewers in Sydney, a short description of the way in which the pipes are manufactured will not be out of place. The principal material of which the pipes are made is dark coloured shale, known as Wianamatta shale. This is ground by a disintegrator to a uniform powder, to which a small quantity of water is added, and the whole is then mixed to the consistency of very stiff puddle clay, in which condition it is fed to the machine for making the pipes. The pug is thrown or shovelled into a hollow vertical cylinder, whose internal diameter is the external diameter of the barrel of the pipe. The mould for the exterior of the collar is fixed under the floor, above which the piston works when forcing the pug downwards through the cylinder, above described, and into the collar mould at the lower end of the cylinder.

The exterior collar mould is made in two pieces, which are opened when removing a moulded pipe, and remain open till the mould for the interior of the collar is placed in position and held there by a piston from below. A square board is placed between this piston head and the interior collar mould, to enable the workmen to remove the pipe when completely moulded. When the pressure of the top piston is applied, the collar is formed while the lower portion remains fixed. The upper piston is then withdrawn, the lower piston is set free to move, so that when the pressure is again applied to the top piston, the pug is forced down inside the cylinder, and outside a bell-shaped piece of metal whose exterior diameter at the base is the interior diameter of the pipe,

the bell being fixed concentrically with the cylinder in which the upper piston works.

Under pressure of top piston, the lower piston descends for 2 feet, when it is stopped. The moulded pipe is then cut off with a fine wire, and removed on the board with the interior collar mould still in it. Another board is placed on the piston head, another interior collar mould is placed in position, the lower piston is raised till the board touches the inner collar mould, and the operations are then repeated.

After moulding, the pipes are partially dried in sheds or in partly cooled kilns before burning. In the kilns they are stacked as close as possible, the smaller sizes being placed inside the larger ones. The pipes are also stacked one above another to the full height of the kiln. After burning for about a week, and while the material is white hot, salt is thrown into the kiln with the last three or four charges of fuel to form the glaze, and shortly after the burning ends. The kilns and contents are allowed to cool slowly to the temperature of the outside air very nearly, and the pipes are then ready for use.

Testing Machine.

The machine used for testing the pipes for crushing, consists of an oil ram which descends on a block of wood placed on the middle of the pipe lying horizontally in a bed of moist sand, contained in a wrought iron box about 3 feet square. At each of the four corners of this box, a large screw is fixed vertically. The upper and working part of the machine is carried on these four screws, so that it can be raised or lowered to suit the different sizes of pipe, varying from 6 inch to 24 inch internal diameter. The raising or lowering is effected by a horizontal band wheel on one screw. Turning this handle causes a toothed wheel of small diameter to revolve, and in doing so to turn a toothed wheel of large diameter, which causes a toothed wheel of small diameter to revolve on each of the other three vertical screws. In this way all four corners are raised or lowered equally. Resting on these four toothed wheels, and screwed by bolts to the under side of the

large toothed wheel, is a cast iron cylinder of 9 inch internal diameter, the piston being 7 inch diameter. This piston exerts a pressure on a block of wood 6 inch square, curved on its lower face, to suit the outer circumference of the pipe. The pressure is obtained by pumping oil into the top of the cylinder, causing the piston to descend till the pipe breaks, when the pressure is read off on a pressure gauge attached. The oil is pumped from a reservoir on the machine, into the main cylinder, through a small cylinder shown end on in the photographs. In this small cylinder are five openings for oil to pass, three being on the side next the reservoir, and two being on side next the main cylinder: of the three the centre one is for the suction pipe, while the other two exhaust oil from the top and bottom of the main cylinder alternately. Of the two openings in the other side of the small cylinder, one connects by a pipe with the top of the main cylinder and the other with the bottom. The piston of the small cylinder is moved by a hand lever. In one position, the oil is pumped from the reservoir into the top of the main cylinder causing the piston to descend, and at the same time to force any oil below the piston head back into the reservoir.

The pipe having been broken, the position of the small piston is altered, so that oil is pumped into the bottom of the main cylinder as the piston rises, the oil above the piston head is forced back into the reservoir, so that the same oil can be used over and over again.

The principle of the machine was supplied by Mr. J. M. Smail, M. Inst. C.E., and the details were worked out in the drawing office of the Road and Bridges Branch of the Public Works Department, under the supervision of Mr. J. A. Macdonald, M. Inst. C.E. The machine was locally made and has been in use for about thirteen years. The two photographs show a pipe just before and just after breaking in the machine.

Before a specification was drawn up, it was found necessary to obtain some data as to the pressure the local pipes would stand. By the direction of the late Mr. W. C. Bennett, M. Inst. C.E., Engineer-

in-Chief for Sewerage construction, short lengths of pipe were specially manufactured, so that they might be tested by Professor Warren, at the University. Using the results so obtained as a guide, the following specification was drawn up:—

"20. *Stoneware pipes and junctions* to be of well-ground and mixed materials of tough, tenacious, impervious quality, well burnt, sound, hard, uniform in thickness, true in section, straight longitudinally, uniformly glazed both inside and outside, free from fire or other cracks, flaws and ash holes, the collar and barrel to be made in one piece, and in every way equal to sample pipe to be seen at the Engineer's office.

"21. Pipes to be of the following thickness and depth of collar, viz.:—

Pipes inside diameter,	4-in.;	thickness,	$\frac{5}{8}$-in.;	depth of collar,	$1\frac{3}{8}$-in.
„	„	6-in.;	„	$\frac{3}{4}$-in.;	„	$1\frac{5}{8}$-in.
„	„	9-in.;	„	$\frac{7}{8}$-in.;	„	2-in.
„	„	12-in.;	„	1-in.;	„	2-in.
„	„	15-in.;	„	$1\frac{1}{4}$-in.;	„	$2\frac{1}{4}$-in.
„	„	16-in.;	„	$1\frac{3}{8}$-in.;	„	$2\frac{1}{4}$-in.
„	„	18-in.;	„	$1\frac{1}{2}$-in.;	„	$2\frac{1}{2}$-in.
„	„	21-in.;	„	$1\frac{5}{8}$-in.;	„	$2\frac{5}{8}$-in.
„	„	24-in.;	„	$1\frac{3}{4}$-in.;	„	$2\frac{3}{4}$-in.

"All parcels of pipes used in these works will be tested in the Departmental testing machine, and submitted to the following crushing strains applied to the centre of the pipe:—

24-inch...	... 110 lbs.	per square inch	of bearing	surface.
18 „ ...	... 100 „		„	„
16 „ ...	... 90 „		„	„
12 „ ...	... 80 „		„	„
9 „ ...	... 100 „		„	„
6 „ ...	... 100 „		„	„

"If the Engineer deems its necessary, the pipes will also be tested for porosity. Should the pipes fracture under the foregoing strains, or be found to absorb more than *two* per cent. of water, then the Engineer may reject the whole of the parcel from which

the pipes were taken. The whole of the expense incurred in testing the pipes shall be borne solely by the contractor, and all pipes injured or broken by the testing shall be immediately replaced by sound pipes, subject to the foregoing tests at contractor's cost."

Since November, 1896, the quantity of water that may be absorbed has been increased to 4 per cent., that is if the pipe is perfect in every other respect, viz., as to shape, glazing, etc., the 2 per cent. being retained if the parcel is not uniformly good on outward examination. Great care is taken in choosing the sample pipe from a parcel, to obtain one that to the eye represents a fair average of the parcel.

The crushing test is conducted with the machine already described, under conditions that represent as nearly as possible, fair working conditions when laid. Before fracture takes place, the whole pipe is gradually pressed into the moist sand, so that it takes a firm and uniform bearing. The fracture occurs suddenly, in the form of a longitudinal crack along the top of the pipe from end to end.

The porosity test is then conducted as follows:—From the broken pipe, two pieces are selected free from cracks produced during crushing, and without any glazed edge, one piece being about 10 or 11 square inches in area, and the other 50 to 60 square inches. These pieces are dried in an oven, weighed, and immersed in water for twenty-four hours. They are then taken out, all superficial water is quickly wiped off, and the weights again taken. The percentage increase in weight is then calculated. The result of the porosity test depends to a large extent on the area of the fractured edges as compared with the area of the glazed portion of the tested sample. It also depends on the presence of laminated cracks, due to imperfect drying before burning. In practice it is found that the smaller pieces give the smaller increase in weight. In the case of the smaller pieces, the proportion of fractured edge to glazed portion is greater than in the large pieces, and therefore the porosity might have been fairly expected to be

greater, but the laminated cracks naturally occur more often in the the large pieces and cause a greater percentage increase in weight.

Results of Tests.

The results show already, that the pipes are very much stronger against crushing than necessary, only two per cent. having failed to reach the standards demanded, and these are far greater than any pressure which the pipes are called upon to resist. Taking tho average depth at which the pipes are laid as 8 feet, and making use of the results obtained by Mr. F. A. Barbour,[1] it is found that the actual pressure of a column of filling 6 inches square, is 128 lbs., the weight of a cubic yard of filling being taken as 28 cwt.

The following table gives the average crushing strain of pipes tested under the wooden block 6 inches square, while bedded in damp sand as previously described:

Crushing.

Internal diameter in inches.	Thickness in inches.	Weight in pounds.	Standard under 6 inch square block in pounds	Actual crushing strain under 6 inch square block in pounds
6	$\frac{5}{8}$	36	3,600	6,701
9	$\frac{15}{16}$	64	3,600	6,675
12	1	97	2,880	6,424
16	$1\frac{3}{8}$	147	3,240	5,205
18	$1\frac{1}{4}$	183	3,600	5,349
21	$1\frac{3}{8}$	240	...	4,618
24	$1\frac{3}{4}$	300	3,960	4,965

In the Sewerage Construction Branch, Public Works Department, the standards have been raised to the following:—9 inches to 21 inches = 5,000 lbs., 24 inches = 5,500 lbs.; owing probably to the fact that the submains laid by that Department are at greater depths than the reticulation sewers.

[1] See paper on "Strength of Sewer Pipes and Actual Earth Pressure," Vol. cxxxii., Proceeding of Institution of C.E.

The following table gives the average percentage by weight of water absorbed by test pieces of pipe after twenty-four hours immersion in water.

POROSITY.

Size in inches	Passed or Failed.	2 % Standard. Percentage increase in weight.	4 % Standard. Percentage increase in weight.
6	Passed	1·46	1·36
	Failed	5·52	4·90
9	Passed	1·48	2·30
	Failed	4·27	6·18
12	Passed	1·66	2·37
	Failed	3·34	5·13
16	Passed	1·15	2·39
	Failed	...	5·58
18	Passed	2·12	2·15
	Failed	3·57	4·78
21	Passed	...	3·14
	Failed	...	4·55
24	Passed	1·18	2·85
	Failed	5·52	...

General average—passed 1·97 per cent.; failed 4·85 per cent. The percentage of failures under 2 per cent. standard was 27. The percentage of failures under 4 per cent. standard was 18.

The following figures show that the pipes which break the more easily are also the more porous:—Average crushing strain of pipes which passed for porosity, 6,317 lbs.; average crushing strain of pipes which failed for porosity, 5,990 lbs.; or a little more than 5 per cent. less strength in pipes that failed for porosity.

In 103 cases, test pieces have been weighed both after twenty-four hours and after forty-eight hours' immersion, with the following result:—No. of pipes, 103; percentage increase in weight after twenty-four hours, 2·14; percentage increase in weight after forty-eight hours, 2·35; or 10 per cent. more for forty-eight hours than for twenty-four hours. Two 9-inch pipes have been tested with an internal pressure of 100 lbs. per square inch without fracture, the joint having failed at this pressure and not the pipe.

Another set of tests was undertaken as follows:—Instead of selecting one pipe only, two were chosen as nearly as possible alike

in every way to the eye. One was tested in the usual way, as previously described, the other was dried for two or three days in the engine-room, then weighed whole, and immersed in water, and again weighed after twenty-four hours and after forty-eight hours. It was then tested to destruction by crushing. Pieces were then selected, both large and small, thoroughly dried, and tested in the usual way, with the following results:—

POROSITY.

Size in inches	No. of sets of tests.	No 1 PIPE. Large pieces. Increase in weight per cent. after 28 hrs.	48 hrs.	Small pieces. Increase in weight per cent. after 28 hrs	48 hrs.	No. 2 PIPE. Whole. Increase in weight per cent. after 24 hrs.	48 hrs.	Large pieces Increase in weight per cent. after 24 hrs.	48 hrs.	Small pieces. Increase in weight per cent. after 24 hrs.	48 hrs.
9	14	2·46	2·72	2·50	2·61	1·72	1·83	2·30	2·47	2·15	2·30
12	9	3·16	3·39	2·90	3·00	2·50	2·69	3·13	3·17	2·91	3·14

Average No. 1 Pipe, pieces, increase in weight after twenty-four hours 2·69 per cent.; after forty-eight hours 2·87 per cent. No. 2 Pipe, pieces, increase in weight after twenty-four hours 2·54 per cent.; after forty-eight hours 2·78 per cent.; whole, after twenty-four hours 2·03 per cent.; after forty-eight hours 2·19 per cent.

The foregoing results cannot be taken as absolutely conclusive, as in some cases the crushing strain of the second pipe was greater than that of the first pipe. Taking the average result as approximately correct, it is found that a pipe saturated with water loses 8 per cent. of its original strength against crushing.

The only other cities in Australasia where sewerage works are in progress, or have been recently carried out, are Melbourne, Adelaide, and Wellington (N.Z.)

Melbourne.—The Melbourne limit for permeability after twenty-four hours immersion of the *whole* pipe, is 4 per cent. A table is given, showing the average results of a number of tests in Melbourne:—

Diameter. Inches.	Thickness. Inches.	Weight Dry.	Weight after 24 hours in water.	Cross breaking 18-inch centres.
24	1½	288	289	3,800
18	1½	186	196¼	3,360

Diameter. Inches.	Thickness. Inches.	Weight. Dry.	Weight after 24 hours in water.	Cross breaking 18-inch centres.
15	$1\frac{1}{4}$	$144\frac{1}{4}$	$146\frac{1}{2}$	3,900
12	1	97	$99\frac{1}{2}$	3,900
9	1	$74\frac{1}{4}$	$78\frac{1}{2}$	3,900
6	$\frac{7}{8}$	$37\frac{1}{2}$	$38\frac{1}{4}$	4,480
4	$\frac{7}{8}$	26	$27\frac{1}{2}$	5,000

Taking the average increase in weight, the result is 3·22 per cent. With respect to internal pressure, the vast majority of pipes tested stood 250 lbs per square inch before bursting, when tested to destruction.

The specified tests are as follows in Melbourne:—

Shape.—Each pipe will be tested by passing into it a wooden dummy, truly cylindrical, or an anulus for the bends, but with a diameter $\frac{3}{8}$-inch less than the specified diameter of each particular size of pipe; and also by passing over the outside of the pipe a ring of an internal diameter $\frac{1}{4}$-inch larger than the external diameter of each size of pipe. Any pipe which these gauges do not fit satisfactorily, will be at once rejected. The pipes will also be examined for uniformity and suitability of burning and glaze.

Internal pressure.—Pipes which have passed as above will then be subjected to hydraulic pressure equal to a column of water 30 feet high, and while under this pressure the pipe will be repeatedly struck with a wooden mallet. Any pipe showing signs of sweating or leakage, either in the body or socket, will be at once rejected.

Permeability and cross-breaking.—The superintending officer shall test as many pipes as he may think desirable, for permeability, and to resist crushing by cross-breaking. The pipes, after being dried to the satisfaction of the superintending officer, shall not absorb more than 4 per cent. of moisture after being immersed in water for a period of 24 hours. The pipes shall bear a cross breaking strain when supported in a cradle on bearers 18 inches apart, of 1,000 lbs, the weight to bear half-way between the cradle on the upper side of the pipe. Should the results of the

cross breaking or permeability be unsatisfactory, the superintending officer may reject as many pipes, bends, junctions, etc., as may, in his opinion, be of inferior quality.

Adelaide.—In Adelaide, the pipes are examined for uniformity and quality of burning and glazing. Every pipe is then tested by passing a dummy into, and a ring over it. Every pipe is then tested with an internal hydrostatic pressure, equal to a column of water 28 feet high, and while under this pressure is struck repeatedly with a wooden mallet. A pipe showing signs of sweating or leakage is rejected.

After the foregoing tests, the pipes may be tested for strength to resist crushing, and for permeability. In practice the pipes proved so very satisfactory that the latter tests were generally omitted.

About one per cent. only failed to pass the whole of the tests imposed.

Wellington.—In Wellington, N.Z., the pipes were tested:—(1) For shape; (2) For uniformity and quality of burning, glazing, etc.; (3) Under hydrostatic pressure, equal to a column of water 25 feet high, while being struck with a wooden mallet; (4) For crushing, and must stand pressure of 100 lbs. per square inch, applied at centre of pipe; (5) For porosity, and must not increase more than 2 per cent. in weight after 24 hours immersion.

The pipes were not tested to destruction, but many of them were tested up to 60 lbs. per square inch internal pressure without showing any defects.

In Melbourne, Adelaide, and Wellington the constructing authorities let contracts for the supply and delivery of all pipes at central depôts, where every pipe was tested. The Sydney practice has been to test pipes supplied for each particular contract.

For the purpose of comparison, the average results of sixteen tests of 2 feet 5 inches × 1 foot 9 inches oviform Monier pipes for sewer construction are added. The area of cross section is equal

to a circular pipe 2 feet in diameter, wire netting is inserted in the body of the material, and wire is spirally wound round in the body of the material, also a horizontal base 7 inches wide is provided:—

Number of Pipes.	Thickness in inches.	Age in days.	Pressure at first fracture under 36-inch block.	Pressure at final fracture under 36-inch block.
16	2	100	6,384 lbs.	10,675 lbs.

The following table shows that even after the final fracture these pipes spring back half-way to the original shape when the pressure is removed:—

Number of Pipes.	Original size.	Size under greatest pressure.	Size after pressure removed.
10	2 ft. $4\frac{29}{32}$ in. × 1 ft. $9\frac{1}{4}$ in.	2 ft. $4\frac{3}{32}$ in. × 1 ft. $10\frac{1}{16}$ in.	2 ft. $4\frac{9}{16}$ in. × 1 ft. $9\frac{1}{4}$ in.

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